U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-296 584

Central Florida Phosphate Industry Areawide Impact Assessment Program. Volume I: Description of Program and Industry

Texas Instruments, Inc., Dallas

Prepared for

Environmental Protection Agency, Atlanta, GA. Region IV

Sep 78

EPA 904/9-79-034a
September 1978

PB 296584

CENTRAL FLORIDA PHOSPHATE INDUSTRY AREAWIDE IMPACT ASSESSMENT PROGRAM

Volume I: Description of Program and Industry

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P.O. Box 225621
Dallas, Texas 75265

PUBLISHED SEPTEMBER 1978

Availability Unlimited

Prepared
For

THE UNITED STATES
ENVIRONMENTAL
PROTECTION
AGENCY

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

PB296584

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle

CENTRAL FLORIDA PHOSPHATE INDUSTRY AREAWIDE IMPACT ASSESSMENT PROGRAM - Volume I: Program and Industry Description

5. Report Date: September 1978

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

TEXAS INSTRUMENTS INCORPORATED
P. O. Box 225621
Dallas, Texas 75265

10. Project/Task/Work Unit No.: 08-01-4196

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

The United States Environmental Protection Agency
Environmental Impact Statement Branch
345 Courtland Avenue, Region IV
Atlanta, Georgia 30309

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

It is appropriate that Texas Instruments 7-volume report on the central Florida phosphate industry areawide impact assessment for the Environmental Protection Agency begin with a comprehensive description of the industry itself. This is the purpose of Volume I.

How phosphate rock is recovered, beneficiated, and used and what coproducts result from mining it are discussed, as well as specific locations of the activities and the industry's mine-land reclamation practices.

Also included are world, U.S., state, and study-area production and use statistics.

17. Key Words and Document Analysis. 17a. Descriptors

Beneficiation
Land reclamation
Mineral economics
Mineral resources
Mining
Phosphate deposits
Production capacity
Reserves
Strip mining

17b. Identifiers/Open-Ended Terms

17c. COSATI Field Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 98
	20. Security Class (This Page) UNCLASSIFIED	22. Price PC A05/MF A01

FOREWORD

This is one in a series of reports presenting information developed by, or supplied to, Texas Instruments Incorporated (TI) while conducting an areawide environmental impact assessment of the central Florida phosphate industry for the Environmental Protection Agency (EPA). Because of the diversity and number of groups and individuals interested in this program, the EPA and TI encouraged active public involvement by making working papers available for review and comment as they were developed through environmental analysis, impact assessment, and alternative selection. These working papers then were prepared as a series of reports incorporating the original material modified through the incorporation of comments and additional information developed by TI. Other reports in the series include:

Volume	Title
II	Environmental Permits and Approvals Relating to Phosphate Mining and Fertilizer Manufacturing in Florida
III	Socioeconomics
IV	Atmosphere
V	Water
VI	Land
VII	Impacts of Alternative Public Policies on Social, Economic, and Natural Environmental Systems

These reports are made available through the National Technical Information Service to serve as background information to the environmental statements (draft and final) and environmental planning needs of federal, state and local agencies as well as other interested parties. The information will be of value to those involved with development and regulation of the phosphate industries, others who plan developments in central Florida, and environmental planners in general who must deal with environmental issues on a regional basis. It is hoped their use will lead to good decisions. It has often been said that decisions are only as good as the information on which they are based. Extending that philosophy, decisions are only as good as the decision makers' understanding of the adequacy of the information in resolving the issues being examined.

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SECTION 1
INTRODUCTION

Naturally occurring rock containing one or more phosphate minerals, usually calcium phosphate, is generally referred to as phosphate rock. Commercially, the term is applied to phosphatic occurrences of sufficient purity and quantity to permit their use, either directly or after concentration, in manufacturing commercial phosphate products. Phosphate rocks of the Central Florida Phosphate District, fully within the 7-county study area, include phosphatized limestomes, sands, and clays as well as phosphate pebbles (nodular phosphate) referred to as either "land pebbles" or "river pebbles," depending on the locale of occurrence. (The origin of pebble phosphate and its geochemical and mineralogical aspects are discussed in Section 3 of Volume VI.) The Central Florida Phosphate District encompasses phosphate deposits underlying an area of approximately 5,180 square kilometers (2,000 square miles) in Polk, Hillsborough, Manatee, Hardee, and DeSoto counties (Cathcart 1971).

Florida deposits were first discovered in 1879 near Hawthorn north of the Central District, followed closely by the discovery of river pebbles and large quantities of phosphatized vertebrate fossils in 1881 along the Peace River in the study area. Hand labor and low production characterized the exploitation of the early deposits. In the late 1880s, land-pebble deposits were discovered near the river-pebble occurrences, and their exploitation was initiated in 1888. Because of steadily increasing demands for fertilizer, mining quickly shifted to the very large, easily mined land-pebble deposits. By 1892, the total production of phosphate rock in the Central District was about 280,000 metric (308,700 short) tons (Cathcart 1971). (Section 4 of this volume summarizes more recent production of phosphate in the area.)

Since its inception, the Florida phosphate industry has recorded continued technological improvements that have permitted more complete

recovery of existing deposits while keeping the unit cost of production relatively low. Among the most significant early mining improvements were the introduction of small dredges that allowed ore below the near-surface water table to be mined, hydraulic mining techniques, draglines for removing overburden and ore and, in 1929, the introduction of flotation processes in beneficiation (upgrading) of ore to permit recovery of fine-grained phosphate formerly discarded.

Until the introduction of flotation, phosphate mining tailings were essentially an admixture of fine phosphate dry sands and clays, which was quite suitable as landfill; with flotation, however, the clays are bound in an aqueous solution called clay slimes, presenting unique and expensive disposal problems and making complete mine land reclamation somewhat impractical.

Today, the phosphate industry in the study area is a large and highly diverse industry producing primarily a product that is essential to agriculture as practiced in the United States and the world. In the following sections, information is presented which describes the basic uses of phosphate rock, potential coproducts from phosphate mining in the area, specific locations and activities of the industry, potential effects on the natural environment of the area because of industry activities, mine land reclamation practices, phosphate reserves and resources of the world and within the study area, and resources other then phosphate existing in the study area. Also included is a glossary of the terminology used by the phosphate industry in describing its activities and products.

SECTION 2

PHOSPHATE USES AND POTENTIAL COPRODUCTS

A. PHOSPHATE USES

Phosphate rock has diverse agricultural and industrial uses, but the quantity used domestically for agricultural purposes always exceeds that used for all other purposes.

By far the greater portion for agricultural use goes into the preparation of ordinary, ammonium phosphate and triple superphosphates (discussed in Section 3); the former contains 16 to 20 percent available P_2O_5 and the latter 42 to 50 percent P_2O_5. Elemental phosphorus and phosphoric acid go into inorganic and organic chemicals that are used as leavening agents, water softening and cleansing products, plasticizers and insecticides as well as for many other industrial uses and purposes. Elemental phosphorus is also used by the military for smoke screens and incendiary bombs and is used in pesticides and phosphorus alloys and by the electrical and electronics industries (e.g., for fluorescent lights and television tubes). Phosphoric acid is used also in producing fertilizers, animal feed supplement, beverages, and ceramics; as a catalyst and oil refining agent; and in photography and dental and silicate cements (Ruhlman 1956).

In 1966, approximately 50 percent of phosphate rock produced in central Florida was captively used near the mine sites to manufacture phosphoric acid, high-analysis fertilizers, and elemental phosphorus; approximately 25 percent was sold to domestic fertilizer manufacturers and the remaining 25 percent was exported. More than two-thirds of the domestic demand was for agricultural use, whereas one-third was for industrial purposes. Being relative figures, these tend to vary from year to year (Sweeney and Hasslacher 1970). Figure 2.1 shows this generalized use pattern.

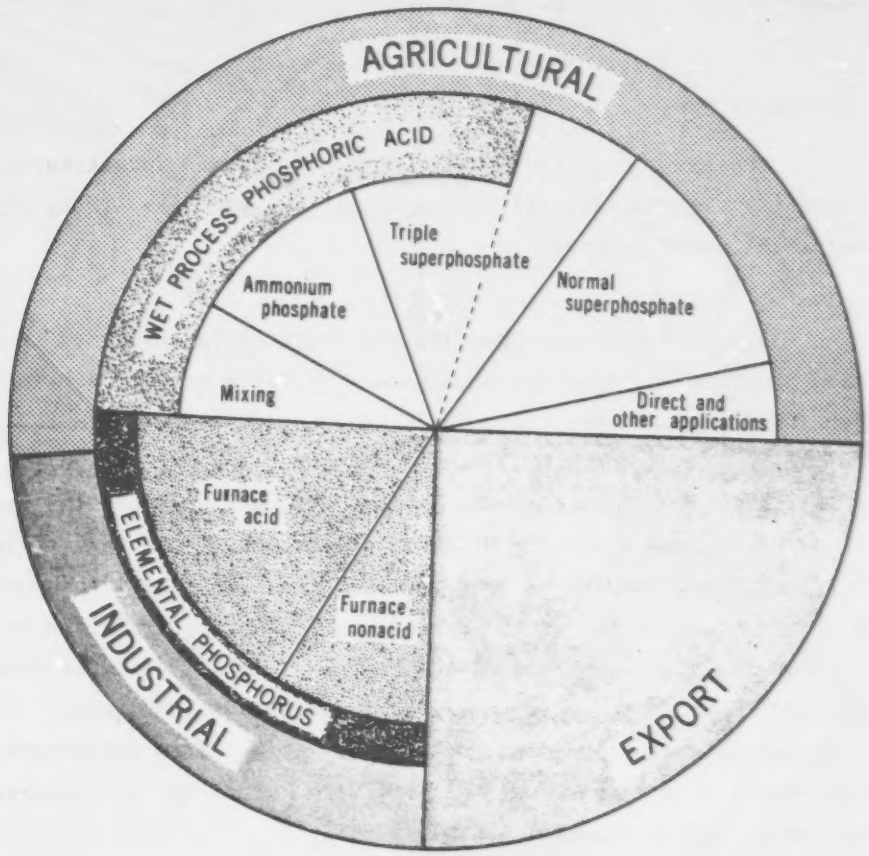


Figure 2.1. Generalized Phosphate Rock Use Pattern (McBride et al 1966 as cited by Sweeney and Hasslacher 1970)

By the mid-1970s, essentially all phosphate rock produced in Florida for domestic consumption was used to produce wet-process phosphoric acid. Nationally, about 82 percent of the phosphate rock consumed was for agricultural purposes; the remaining was consumed as elemental phosphorus or as other products (Stowasser 1974). Section IV presents usage and production in more detail.

B. MARKET DISTRIBUTION

The proximity of the central Florida phosphate deposits to the Gulf of Mexico and Atlantic Ocean has facilitated their development because it has given the industry in the study area the advantage of reasonable distribution costs (compared with those for western states, for example) by ocean freighters and ocean and river barges. The industry also can use all-rail shipments and/or a combination of water and rail transport in response to demand, availability, or other impact factors of these product distribution systems (Sweeney and Hasslacher 1970). Figure 2.2 shows the water routes of barge traffic carrying phosphate rock and fertilizer products to domestic markets, as well as generalized ship movements to export markets, for the phosphate producers in the southeastern United States.

Primarily rail transports marketable phosphate rock and fertilizer products from the study area processing plants to port terminals on the Gulf Coast for export or domestic water shipment. Each processing plant has a rail spur for direct shipment to the ports, and the 1-way rail haul is about 48 to 64 kilometers (30 to 40 miles). Rail also moves a small amount to domestic manufacturers (Sweeney and Hasslacher 1970). Contract trucking moves a small quantity from the processing plants to port terminals, primarily for domestic barge shipment to the upper Gulf Coast. All of the phosphate operations in the study area are served by the Seaboard Coastline Railroad, which maintains a special fleet of rail cars to move phosphate rock from the mines to the port terminals. Car capacities range from 45.4 to 90.7 metric (50 to 100 short) tons.

According to Sweeney and Hasslacher (1970), the years have brought changes in the marketing of phosphate rock and fertilizer products. "In the 1940s, the general practice of the fertilizer industry was to ship raw material rather than a finished fertilizer to a consuming area. Small fertilizer plants in the southeast and midwest converted the raw material to plant nutrients. In the 1950s, this concept changed because transportation costs strongly influenced the location of the chemical plants. Plants that produced low analysis materials tended to be located close to the fertilizer

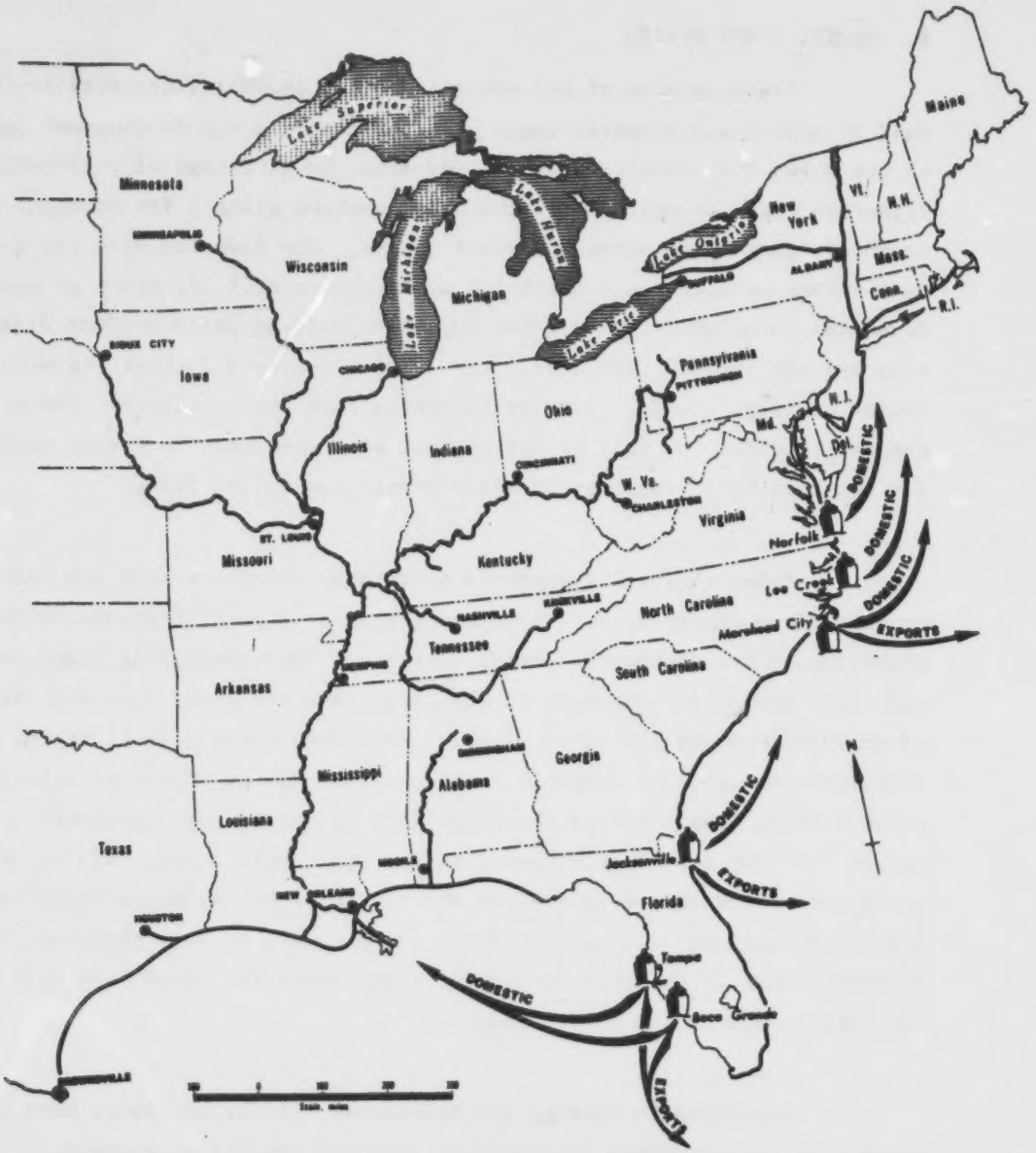


Figure 2.2. Inland and Intracoastal Water Routes Available for Ship and Barge Movement of Phosphate Rock in Eastern United States (Sweeney and Hasslacher 1970)

market, whereas those manufacturing high analysis material tended to be near the phosphate mine. For example, 30 percent P_2O_5 phosphate rock is shipped to plants producing superphosphate containing only 20 percent available P_2O_5; thus, the 30-percent material lowers the freight charge per unit of P_2O_5 shipped." The trend, then, was to construct large chemical complexes that manufacturered high-analysis fertilizers near the Florida phosphate mines. Converting the 30-percent P_2O_5 phosphate rock into a 33 to 44 percent P_2O_5 product lowered the freight charge per unit of P_2O_5 shipped (McBride et al 1966 as cited by Sweeney and Hasslacher 1970).

"In the 1960s," according to Sweeney and Hasslacher (1970) "the Florida phosphate industry went from a period of relative status quo to a period of rapid expansion. The many mergers between fertilizer companies and oil and chemical companies, resulting in integrated companies, were probably the foremost factor in this expansion. Also, increased domestic and foreign demand for phosphate rock had to be met. Early in 1967, the logistics of the industry were restructured, resulting in a changing marketing pattern for some Florida phosphate rock. The Florida marketing patterns were (1) domestic shipments of dry phosphate rock to the upper Gulf Coast with sulfur returned to Florida; (2) dry phosphate rock shipments along the Atlantic seaboard; and (3) dry phosphate rock exported."

Although the general pattern just described still exists, shipping patterns significantly changed in the late 1960s as a number of new chemical fertilizer plants were constructed on the Gulf Coast and lower Mississippi River adjacent to sulfur deposits and low-cost natural gas. Natural gas is used for ammonia manufacture and production of diammonium phosphate as well as for drying rock. (See Section 3 for definitions of products.)

C. POTENTIAL COPRODUCTS

Major potential coproducts of the phosphate industry of the study area include the following:

- Phosphate from the aluminum phosphate zone immediately above the primary ore body predominantly in the central and northeast portion of the area. (Material zonations in the study area are described in Section 2 of Volume VI.)

  The aluminum phosphate zone is a potential resource of phosphate as well as alumina and uranium. The Tennessee Valley Authority has directed much research toward recovering phosphate from similar zones at other localities, but rock from this zone is currently being discarded with the overburden (Altschuler et al 1962).

- Alumina

  Alumina, from which aluminum is made, is not presently being recovered in quantity. About one-half of the alumina mined with phosphate goes into sold phosphate products and the remainder to waste (Altschuler et al 1962). Alumina that is now discarded could be recovered from the aluminum phosphate zone, as has been demonstrated with similar zonations in Senegal, and thus could be considered a potential coproduct easily mined and beneficiated along with the ore currently being mined. This represents a resource of hundreds of millions of tons of elemental aluminum (Altschuler et al 1956).

- Uranium

  Several plants in the study area have experimentally recovered uranium from phosphoric acid, and commercial recovery appears to be nearing reality. Large-scale recovery of uranium has been delayed because of economic and technologic problems, but these appear to have been solved. The most likely processes to be used involve liquid-liquid solvent extraction processes. Uranium Recovery Corporation (URC), a division of United Nuclear Corporation, has installed a uranium recovery module consisting of two units, one at the phosphoric acid plant of W. R. Grace & Company near Bartow and the other at URC's central processing plant near mulberry. The acid-plant unit is involved in initial extraction and stripping, while the central-plant unit is involved in final production of yellow cake (U_3O_8) (*Engineering and Mining Journal* 1975). Wright (1974) estimates that approximately 1,800 metric (2,000 short) tons of uranium could be recovered annually from the phosphate rock processed in the study area. The U.S. Energy Research and Development Administration (ERDA) estimates that more than 900 metric (1,000 short) tons of U_3O_8 will be extracted in the study area by 1978; this would represent approximately 8 percent of the 1975 production of nearly 11,156 metric (12,300 short) tons (USERDA 1976).

SECTION 3

ACTIVITIES OF CENTRAL FLORIDA PHOSPHATE INDUSTRY

The central Florida phosphate industry is a part of the southeastern segment that includes northern Florida, Tennessee, and North Carolina. Most of the major producers in central Florida are vertically integrated; i.e., they mine, process, manufacture, and market: the remainder have only manufacturing and marketing facilities. Through 1968, the Central Florida District, which is fully contained within the 7-county study area, accounted for more than 92 percent of Florida's phosphate production (Cathcart 1971). Companies active in the study area are listed in Table 3.1 with their specific activities; the locations of these activities appear in Figure 3.1 (in pocket).

Table 3.1. Phosphate Industry Activities (Major Companies Only) in Study Area*

Company	Location	Activity
Brewster	Lonesome	Mining, beneficiation, drying
	Haynsworth	Mining, beneficiation
Swift	Silver City	Mining, beneficiation, drying, grinding, normal superphosphate, sulfuric acid
	Watson	Mining, beneficiation
USS Agri-Chem	Bartow	Drying, grinding, sulfuric acid, phosphoric acid, nitrogen-phosphate grades
	Ft. Meade	Drying, grinding, sulfuric acid, phosphoric acid, triple superphosphate, fluorine products
	Rockland	Mining, beneficiation, drying
Gardinier	East Tampa	Normal superphosphate, sulfuric acid, phosphoric acid, triple superphosphate, nitrogen-phosphate grades, fluorine products, furnace slag
	Ft. Meade	Mining, beneficiation, drying
Borden	Palmetto	Sulfuric acid, phosphoric acid, triple superphosphate, nitrogen-phosphate grades
	Tenoroc	Mining, beneficiation, drying
	Plant City	Animal feed grades
T/A Minerals	Mulberry	Mining, beneficiation
Electro-phos	Bartow	Drying, elemental phosphorus
IMC	Clear Springs	Mining, beneficiation
	Kingsford	Mining, beneficiation, drying, grinding
	Noralyn	Mining, beneficiation, drying, grinding
	New Wales	Sulfuric acid, phosphoric acid, superphosphoric acid, triple superphosphate, nitrogen-phosphate grades, animal feed grades
Farmland Ind	Bartow	Sulfuric acid, phosphoric acid, triple superphosphate, nitrogen-phosphate grades, ammonium sulfate
Mobil	Nichols	Calcining, drying, grinding, elemental phosphorus
	Nichols	Mining, beneficiation
	Ft. Meade	Mining, beneficiation
Agrico	Pierce	Beneficiation, drying grinding
	South Pierce	Sulfuric acid, phosphoric acid, triple superphosphate, fluorine products
	Payne Creek	Mining, beneficiation
	Saddle Creek	Mining, beneficiation
	Fort Green	Mining, beneficiation
W. R. Grace	Bartow	Drying, sulfuric acid, phosphoric acid, triple superphosphate, nitrogen-phosphate grades
	Hooker's Prairie	Mining, beneficiation
	Bonny Lake	Mining, beneficiation, drying
Royster	Bartow	Grinding, sulfuric acid, phosphoric acid, triple superphosphate, nitrogen-phosphate grades
Conserv	Nichols	Drying, Sulfuric acid, phosphoric acid, triple superphosphate, nitrogen-phosphate grades
CF Industries	Plant City	Sulfuric acid, phosphoric acid, triple superphosphate, nitrogen-phosphate grades, fluorine grades
	Bartow	Sulfuric acid, phosphoric acid, nitrogen-phosphate grades, fluorine grades

*McNeill 1977a; Florida Department of Environmental Regulation 1977.

Unless otherwise noted, the material presented in this section was derived directly from Cathcart's article "Phosphate Deposits in Florida," which was in the *Journal of Phosphate Chemists Association* (Cathcart 1971), and from McNeill's *Summary of Phosphate Industry and Effects* (McNeill 1977b).

A. MINING

Polk and Hillsborough Counties are the hub of the study area's mining activities, although producing companies in DeSoto, Hardee, and Manatee counties own phosphate lands. Until several years ago, the grade of deposits in the latter counties was thought to be too low for profitable mining. However, with the finite limit of the "high-grade" ore (greater than 70 percent BPL)* and the advancing technologies, which tend to lower phosphate unit costs and increase the degree of recovery of phosphate, the lower grade areas (55 to 70 percent BPL) are being looked at favorably by the mining companies. In fact, six companies have indicated that they may open mines in these lower grade areas in the near future, as evidenced by their seeking permits to mine. (See Figure 3.1 in pocket.)

1. Prospecting

Before effort and funds are committed to the opening of new mines, there must be detailed prospecting to determine the prospect's economic potential. The primary phosphate prospecting tools used in the central Florida study area is the truck-mounted 4-inch core drill. Other tools range from such standbys as geologic reconnaissance and well drilling records to the more exotic airborne gamma-ray spectrometry. Core drilling is programmed, depending on the detail sought; for example, rank reconnaissance prospecting can be conducted by obtaining core samples on 259.2-hectare (640-acre) centers, more detailed reconnaissance on 16.2-hectare (40-acre) centers, land purchasing from 4-hectars (10-acrs) core-sample centers, and mine pit boundary definitions e.g. detailed mine planning from 1-hectare (2.5-acre) or less centers. Core drilling may go as deep as 24.4 to 30.5 meters (80 to 100 feet), depending on the particular depth and thickness of the

*Bone phosphate of lime or tricalcium of phosphate [$Ca_3(PO_4)_2$].

matrix at a particular location, normally terminating within the unweathered underlying Hawthorn limestone geologic formation. The depth at which the cores are first preserved is usually 7.6 to 10.7 meters (25 to 35 feet) below the surface, depending on local circumstances. The cores are analyzed to determine the character of the matrix (ore), i.e., the percentage of occurrence of the various phosphate particle sizes in the ore zone, the thickness and depth of the zone, and other essential factors; from these, the probably unit cost of mining and the resultant potential impacts on processing costs, including ore transport costs, are determined.

From the driller's logs and geological observations of cored overburden, water conditions and bank stability within a potential mine are predicted. The phosphate matrix horizon is normally more impervious than the overlying overburden, so large amounts of ground water may occur immediately at the top of the ore section. Depending on the thickness and permeability of the overburden section, varying volumes of water commonly drain into a new mining cut, posing one of the largest problems to production and recovery of ore. Without control, the mining cut is flooded and the ore section inundated. Mining by dragline under these conditions results in poor recovery through heavy dilution of the ore extracted. Thus, in predicting mine conditions, geologists include predictions of water problems. The individual cut sequences during mining operations are designed so that mine drainage is most readily accomplished (Fountain and Zellars 1972).

One of the more effective methods of controlling water originating from the surface water table is to provide pit pumps and connector wells at the mine site: the pit pumps dispose of water from the ore and overburden zones, which may be drained into the lower Floridan water zone through the connector wells or deposited in surface ponds or streams. By the connector well method, the head difference between the surface water table and the upper Floridan aquifer will not change so drastically as would be the case if pit pumps discharged into surface streams. Connector well systems also include observation wells and surface monitoring stations.

A final prospecting summary may include a legal description of the area, the minable area, total minable tonnage, average tonnage per acre, average depth of the deposit, average percent of phosphate rock in the ore zone, average overburden per acre and per ton, and the specific chemical analyses of the various separated portions.

2. Matrix Extraction

In the Central Florida Phosphate District within the study area, phosphate occurs as small grains and pebble rock normally embedded in soft limestone, clay, and sand that may be as thick as 12.2 to 15.2 meters (40 to 50 feet) and may lie 3.1 to 18.3 meters (10 to 60 feet) below the surface. The phosphate ore-bearing material is known locally as "matrix." The diameter of the matrix pebbles may be as large as 50 millimeters (2 inches) or more or smaller than 0.05 millimeter (0.002 inch) in phosphatic clay (Patton 1963). Matrix composition varies according to location in the field. The matrix is covered by overburden consisting primarily of clay and sand intermixed with some low-grade phosphate.

Mining in the area is done predominantly with electric-powered walking draglines equipped with buckets having capacities of 15.3 to 49.7 cubic meters (20 to 65 cubic yards) and booms of 50.3 to 83.8 meters (165 to 275 feet). The accepted practice is to strip the overburden and mine the phosphate by successive moves of the draglines. Cuts usually are 45.7 to 76.2 meters (150 to 250 feet) wide, a hundred meters to 1.6 kilometers (1 mile) or more long, and 15.2 to 21.3 meters (50 to 70 feet) deep. The initial opening, or box cut, in a new area requires that the spoil be placed on top of natural ground: complete extraction and pit drainage cannot be maintained if all spoil is placed in the pit. The land is prepared for the initial cut and succeeding cuts, where the mine-land must be cleared of trees, swamps drained, and muck or peat removed. After the matrix has been removed from the initial cut, spoil from succeeding cuts is side-cast into the opening. In advancing the mining face, the draglines generally make short moves of 23 to 38 meters (75 to 125 feet) and the over-

burden then stripped to permit ore removal by the dragline; as the ore is removed, it is stacked at natural ground level outside the cutline in a previously prepared suction well or sluice pit. Hydraulic monitors (high-pressure water guns) "slurry" the ore into the suction of centrifugal pumps for transportation to the washing plant. It is currently standard practice in the land-pebble district to hydraulically transport the ore to the washer plant because of the level terrain, the wet beneficiation process used, and the excellent pumping characteristics of the ore. Maximum pumping distances from mine to plant may be as long as 9.7 kilometers (6 miles) (Sweeney and Hasslacher 1970). The matrix slurry is moved to the washer plants through pipelines that are up to 50 centimeters (20 inches) in size. Uniform flow at critical velocity [4.6-5.5 meters (15-18 feet) per second] is maintained so there will be no waste of energy and matrix will not settle to clog the pipeline between pumping stations (Hoppe 1976). The actual pumping rate at a given facility or mine is a function of the precise slurry density (about 40 percent solids), the preciseness of the density monitoring equipment, and the ability of the operators to adjust to changing conditions.

The current mining rate in the study area is about 1,620 hectares (4,000 acres) per year, which yields approximately 90,700,000 metric (100,000,000 short) tons of ore annually (U.S. Bureau of Mines 1975).

3. Active Operators

Nine companies currently mine phosphate in the Central Florida Phosphate District:

- Agrico Chemical Company, a subsidiary of the Williams Companies
- Borden Chemicals' Smith-Douglas Division
- Brewster Phosphates (American Cyanamid, 75 percent; Kerr-McGee, 25 percent)
- Gardinier Inc., a wholly owned subsidiary of SOPAG

- W.R. Grace and Company
- International Minerals and Chemical Corporation (IMC)
- Mobil Oil Corporation
- Swift Agricultural Chemicals Corporation (an Esmark company)
- USS Agri-Chemicals, a division of U.S. Steel
- TIA Minerals

Four additional companies - Phillips Petroleum, C.F. Industries, Beker Phosphate Corporation, and Mississippi Chemicals - are planning open mines in the future, as evidenced by their submittal of applications for federal and state mining permits.

Mined areas within the Central Florida Phosphate District are shown in Figure 3.1 (in pocket as Plate 1).

4. Potential Effects on Natural Environment

The potential effects of mining activities on the nautral environment generally fall into four areas:

- Land Clearing

  The potential effects of removing vegetation and top soil could increase erosion and cause subsequent siltation of local streams, destroy wetlands and wildlife habitats, reduce the self-purification of swamps and streams in the area by eliminating them, reduce natural streamflow stabilization by vegetation, and have adverse effects on runoff in specific areas.

- Stripping Overburden and Removing Matrix

  Here, the potential effects are essentially the same as those of land clearing but could be more drastic and permanent if the area were not reclaimed. Even with reclamation, permanent alteration will exist, but because of the elimination of shallow-hard pan clay layers and the mixing of sands and clays, the resulting soils are often better for agriculture than the soils existing prior to mining.

- **Matrix Transportation**

  Potential effects associated with matrix transfer can be grouped into three areas: effects associated with land clearing in establishing the slurry pipeline right-of-way, those associated with the use of water resources required to slurry the matrix, and those associated with matrix spills due to (even though infrequent and localized) pipeline breaks.

- **Ground Water**

  One major potential effect on ground water is associated with the potential to lower the head values of the upper Floridan aquifer when the surface water table is pumped during mine dewatering. This can be mitigated partially by using connector wells, as is currently being done by IMC and Brewster Phosphates. A second major potential effect deals with total usage of ground water for mining purposes. These water demands are discussed in detail in Volume V.

B. BENEFICIATION

1. Operations and Techniques

Beneficiation is the application of processes to the mined matrix in order to remove inert materials (e.g., sand) or extremely fine materials that cannot be economically separated (i.e., slimes), thus upgrading the ore. The mechanical processes employed include washing, milling (hammer mill), screening, clarifying, separating, and floating.

The first step in the beneficiation process is to wash the matrix. Material received at the washer plant consists of clay balls, coarse phosphate rock, and a mixture of fine clay, phosphate particles, and silica (quartz sand). The coarse phosphate rock is separated from the clay, silica, and fine phosphate, as shown in Figure 3.2, by means of various types of screens, log washers for washing the coarse or pebble phosphate, and hammer mills for breaking up the clay balls. Matrix is normally reduced to less than 19 millimeters (0.75 inch) in size.

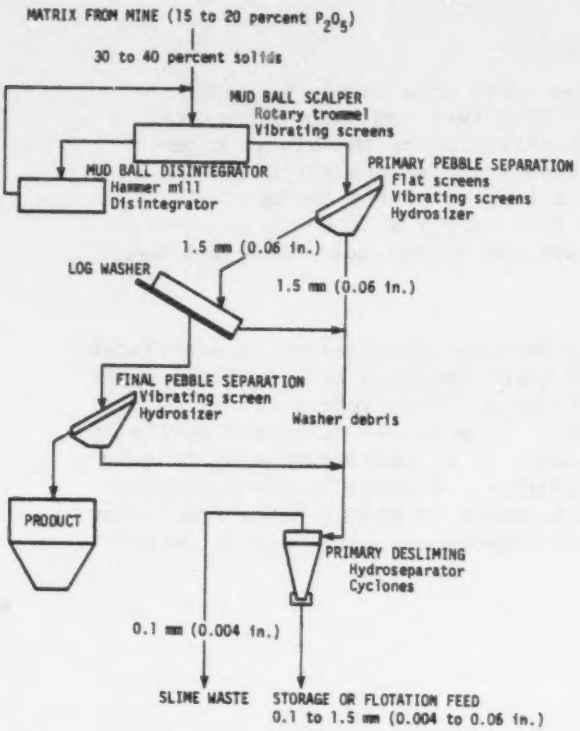


Figure 3.2. Generalized Diagram of Washer Plant (Sweeney and Hasslacher 1970)

At this stage, a clean coarse rock that is between 1.5 and 19 millimeters (0.06 and 0.75 inch) is produced. Material that contains the fine clay, phosphate, and silica and is smaller than 1.5 millimeters is then subjected to cyclones or hydroseparators; these remove as waste slime the materials that are smaller than 0.1 millimeter (0.004 inch). Although the slime material contains approximately 32 percent BPL [tricalcium phosphate — $Ca_3(PO_4)_2$], there is currently no economical method for recovering the contained phosphate values.

The 0.1- to 1.5-millimeter (0.004- to 0.06-inch) product from the primary separation units of the washer plant constitutes the feed (input material) for the primary classification units of the flotation plant. (The washer plant and the flotation plant actions together are called beneficiation.) Following classification, materials larger than 0.5 millimeter (0.02 inch) and those smaller than that are treated separately for recovery phosphate concentrates. Coarse flotation or skin flotation systems collect the coarser material; sequential anionic and catioic flotation separation processes concentrate the finer material. The flotation steps of the beneficiation process are depicted in Figure 3.3. Included is reverse flotation, i.e., flotation applied to both the fine phosphate pebbles and the sand in separate process steps. For flotation involving the phosphate fines, the feed is treated with small amounts of fatty acid, caustic soda, and fuel oil; the caustic soda cleans the small phosphate pebbles along with ammonia and regulates acidity (pH) so that the proper absorption of the fatty acid is possible. The pebbles then take on a film of fuel oil and are floated by the frothing action of the remaining crude soap (caustic soda and fatty acid). In the flotation cells, the whole admixture is

agitated with air, the sand sinking and the small phosphate particles floating and being swept from the surface with paddles. This phosphate product, called rougher concentrate, may be further upgraded in the cleaner circuit or silica flotation circuit (Cathcart 1971). For flotation involving sand, the rougher flotation concentrate is dewatered and then conditioned with a suitable amount of sulfuric acid to scrub the oils from the surface. After being scrubbed, the product is thoroughly dewatered and deslimed. A cationic reagent (amine) is then added to the rougher concentrate as it passes into more flotation cells, where the remaining silica is floated from the phosphate pebble. The high-grade concentrate remains behind in the cells (Cathcart 1971).

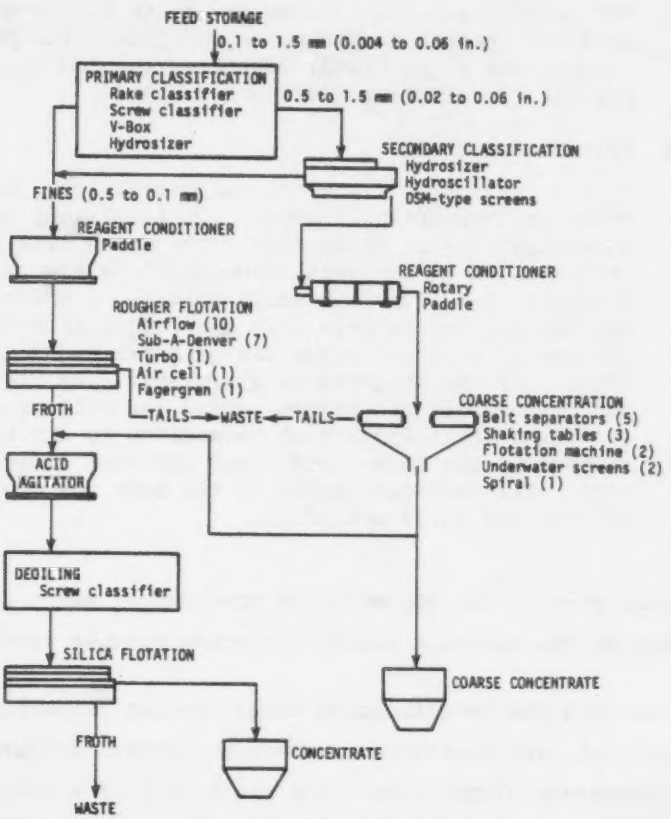


Figure 3.3. Generalized Diagram of Flotation Plant (Sweeney and Hasslacher 1970)

Other coarse-concentrate producing methods include:

- Tabling (no longer in use)

  The feed is again conditioned with caustic soda, fatty acid, and fuel oil and the admixture of reagents and phosphate feed passed over ore-dressing groove-surfaced shaking tables set at a slight angle and vibrated. The oiled phosphate particles are floated over the grooves and off the side of the tables, with the unreagentized sand falling between and following the grooves to the end of the table where it is discharged as tailings (Cathcart 1971).

- Spiral Conduit

  The feed is passed through a modified semicircular cross-section spiral fed at the top with a reagentized slurry that flows down the spiral; there, the phosphate particles, being coated with fatty acid reagents, go to the outside and the sand stays on the inside where it is drawn through portholes as tailings. The rougher concentrate is generally dewatered and fed to additional spirals for cleaning (Cathcart 1971).

- Belt Concentrator

  This is essentially a wide, relatively flat, belt conveyor approximately 23 meters (75 feet) long and having a multiplicity of pipes that spray water over the central section of the belt throughout its entire length. A number of baffles and small riffles directly above and resting on the belt lift the reagentized feet on the moving belt and crowd the material under the spray lines. As the reagentized phosphatic sand fed on one end of the belt progresses toward the tailing end, the phosphate particles attach themselves to air bubbles created by the sprays and float off both sides of the belt. The tailings remain on the belt and are carried off the end (Cathcart 1971).

In most plants, the concentrates produced by belts and spirals are further upgraded by the cationic silica flotation process previously described.

Wastes from the beneficiation stage consist primarily of slimes, quartz sand tailings, and wastewater removed at several different points in the process. Phosphate slimes constitute about half of a beneficiation plant's wastes and contain about one-third of the total matrix mined. Disposal of slimes [material smaller than 0.1 millimeter (0.001 inch)] is of primary concern to the phosphate industry. Early in phosphate mining history,

it was found that the slimes had to be impounded in storage ponds abovegrade because their volume exceeded the volume of matrix removed by mining. (Volume increase is due to the large amount of water locked up by the clay-sized particles.)

Tailings from beneficiation are fairly uniform [0.1 to 1.5 millimeters (0.004 to 0.06 inch)] quartz sand, which is generally disposed of in the mining area either as backfill material or dike-building material for slime-retention dams or is mixed with slimes as a method of dewatering them. (Slime dewatering is discussed in more detail in subsection E.)

After an initial settling and clarification period, most of the water containing the slimes is reclaimed and reused. However, part of this water must be replaced as makeup water as subsequent settling of the slimes, and the release of additional water, is very slow. In Figure 3.4 illustrating the characteristic settling behavior for a "typical" phosphate slime in a pond, the settling rate for these water suspensions exhibits a relatively steep slope at first, followed by a gradual flattening as hindered settling of the colloidal particles becomes more predominant; this causes the solids concentration of the settled material to increase very slowly with time. Particles settle relatively fast in a dilute mixture but, as the particles in suspension become more crowded, the settling rate slows to a point at which, for all practical purposes, an ultimate or limiting density is reached.

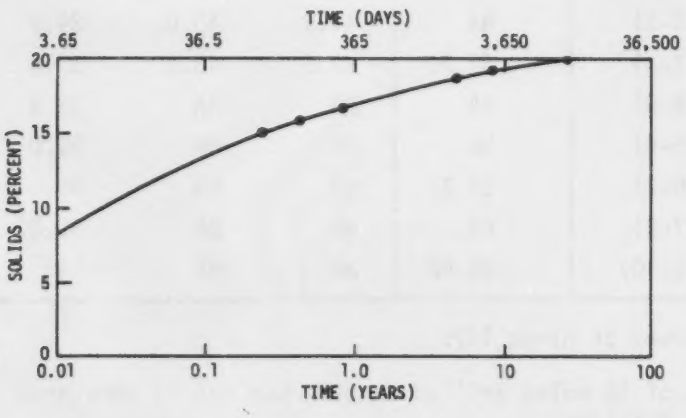


Figure 3.4. "Typical" Rate of Consolidation of Phosphate Slimes (U.S. Bureau of Mines 1975)

The phosphate mining industry requires rather large quantities of water, which may range up to 37,850 liters (10,000 gallons) per minute at the mines and may run even higher in recovery plants (Patton 1963). Water used per ton of phosphate product has been estimated to be 37,850 liters (10,000 gallons) (McNeill 1977b). Water consumed requiring make-up is in the range of 4,542-6,056 liters (1,200-1,600 gallons) per ton of phosphate rock product. Of course, the amount of water used depends on the size of the operation and the methods employed. In most cases, the required makeup water is obtained from wells in the Floridan aquifer.

In the normal course of mining and washing operations, active slime ponds eventually become inactive. In the area, there are a number of ponds that may be as much as 60 years old, but even these have not settled to a solids content. Table 3.2 shows the solids content of an old phosphate slime settling area that was sampled at the beginning and end of a 13-year period; the solids content of the area is seen to be almost unchanged.

Table 3.2. Solids Content of Phosphate Slime in Old Carmicheal Settling Area, Agrico Chemical Company*

Depth [meters (feet)]	Percent Solids			
	1954 Drilling Avg†	1967 Drilling		
		Hole 1	Hole 2	Hole 3
Top 0.3 (1)	50.27	55.0	54.5	57.0
0.3-0.6 (1-2)	NA††	49.5	44.0	43.5
0.6-0.9 (2-3)	NA	41.5	40.0	39.5
0.9-1.2 (3-4)	37.70	37.5	40.0	37.5
1.2-1.5 (4-5)	NA	NA	NA	35.5
1.5-1.8 (5-6)	NA	NA	NA	35.0
1.8-2.1 (6-7)	35.21	NA	NA	36.0
2.1-2.4 (7-8)	NA	NA	NA	35.0
2.7-3.0 (9-10)	39.98	NA	NA	NA

*U.S. Bureau of Mines 1975.

†Average of 12 holes drilled in 1954 but not in same area as 1967 drilling.

††Not available.

Primarily because of the slimes, phosphate recovery is incomplete. An example of a balance sheet is presented as Table 3.3.

Table 3.3. Study Area Phosphate Balance Sheet: Proportions of Recovered and Waste Products*

Percent BPL† in Matrix, Recovered Products, or Waste	Gross Wt [metric (short) tons]		BPL Contents [metric (short) tons]		BPL Contents (% of total)
Phosphate matrix (36%)	90.72	(100.00)	32.7	(36.0)	100.0
Coarse pebble (72.0%)	1.68	(1.85)	1.2	(1.3)	3.7
Medium pebble (72.0%)	2.99	(3.30)	2.2	(2.4)	6.6
Fine pebble (72.2%)	3.27	(3.60)	2.4	(2.6)	7.2
Total pebble (72.2%)	7.94	(8.75)	5.7	(6.3)	17.5
Coarse flotation (75.0%)	5.35	(5.90)	4.0	(4.4)	12.2
Fine flotation (76.0%)	13.61	(15.00)	10.3	(11.4)	31.7
Total flotation (75.8%)	18.96	(20.90)	14.3	(15.8)	43.9
Waste tailings‡ (9.0%)	33.24	(36.65)	3.0	(3.2)	9.0
Slimes, plus 200 mesh (27.4%)	9.98	(11.00)	2.7	(3.0)	8.4
Slimes, minus 200 mesh (34.8%)	20.59	(22.70)	7.2	(7.9)	21.9
Total slimes (32.4%)	30.57	(33.70)	9.9	(10.9)	30.3
Grand total	90.70	(100.00)	33.0	(36.2)	100.7

* U.S. Bureau of Mines 1975.
† BPL = bone phosphate of lime or tricalcium phosphate [$Ca_3(PO_4)_2$].
‡ Tailings from flotation treatment.

2. Active Operators

The 10 major companies currently involved in beneficiation of mined matrix in the study area are:

- Agrico Chemical Company
- Borden Chemicals
- Brewster Phosphates
- Gardinier Inc.
- W.R. Grace and Company
- International Minerals and Chemical Corporation (IMC)
- Mobil Oil Corporation
- Swift Agricultural Chemicals Corporation
- T/A Minerals, Inc.
- USS Agri-Chemicals

Beneficiation plant locations within the study area are shown in Figure 3.1.

3. Potential Effects on Natural Environment

The potential effects of beneficiation (washing and flotation) are associated with water consumption and disposal of sand tailings and slimes (which together constitute approximately two-thirds of the mined matrix). Sand tailings are easily disposed of as slime pond dike material or as basic reclamation material and, as such, are not generally considered to have a significantly adverse impact on the natural environment. Activities associated with disposal of waste slimes, however, pose potentially significant adverse impacts.

The conventional method of slime disposal involves large settling area (hundreds of acres per mine) surrounded by earthern dams or dikes from 4.6 to 12.2 meters (15-40 feet) aboveground. Up to two-thirds of the area mined is left in slime ponds. Inadvertent slime discharges via pond dike breaks or matrix pipeline failures, though infrequent, are significant hazards to environmental quality. While the clay particles are insoluble and nontoxic, the slimes will kill fish and other aquatic orgahisms by clogging gills or other oxygen-transfer surfaces, resulting in suffocation, and will coat streams and estuary bottoms, inhibiting or destroying productivity of organisms for up to several years after slime release.

Between 1940 and 1971, the study area experienced 20 dam breaks ranging in intensity from minor localized damage to one that destroyed aquatic organisms for up to 50 miles of river and estuary (McNeill 1977b). Since 1971, however, there have been no reported incidents of slime pond dam failure, probably because of cooperative programs of dike maintenance and inspection between the industry and regulatory agencies since that date.

C. NONCHEMICAL AND CHEMICAL PROCESSING

Normally, phosphate industry products fall into the following end-use classifications: fertilizers, detergents, animal feeds, food products,

and other (Stowasser 1977b) — the "other," for the most part, including specialized fertilizer materials. Categories are not considered in this discussion, since each product of the industry within the study area is discussed separately; however, for reference to the balance of products, consider the data of Table 3.4, keeping in mind that the majority of raw phosphate rock shipped from the study area is converted to salable phosphorus products at plants located in other states. A more detailed breakdown of the product balance by percentage within the phosphate industry of the United States appears in Figure 3.5.

Table 3.4. Phosphate Rock End Uses, 1975*

Product	Metric Tons [Thousands (Short Tons)]
Fertilizer	24,484 (26,995)
Detergents	2,913 (3.212)
Animal feeds	1,396 (1,539)
Food products	248 (273)
Other	1,985 (2,188)
Total	30,989 (34,167)

*Stowasser 1977a

1. Operations and Techniques

a. Phosphate Rock

Following separation from the gangues of associated materials by washing, classification, and flotation actions referred to as beneficiation, phosphate rock products are developed on the basis of chemical analysis. Chemical analyses of phosphate rock are reported as percent phosphorus pentoxide (P_2O_5) or percent tricalcium phosphate [$Ca_3(PO_4)_2$]. If expressed as tricalcium phosphate or bone phosphate of lime (BPL), conversion can be made by considering that 1.0 percent tricalcium phosphate (BPL) is equivalent to 0.458 P_2O_5. Marketable phosphate rock is graded according to its BPL content in percent. Current exports from the study area include grades 77 to 76 percent, 75 to 74 percent, 73 to 70 percent, 70 to 68 percent, 68 to 66 percent

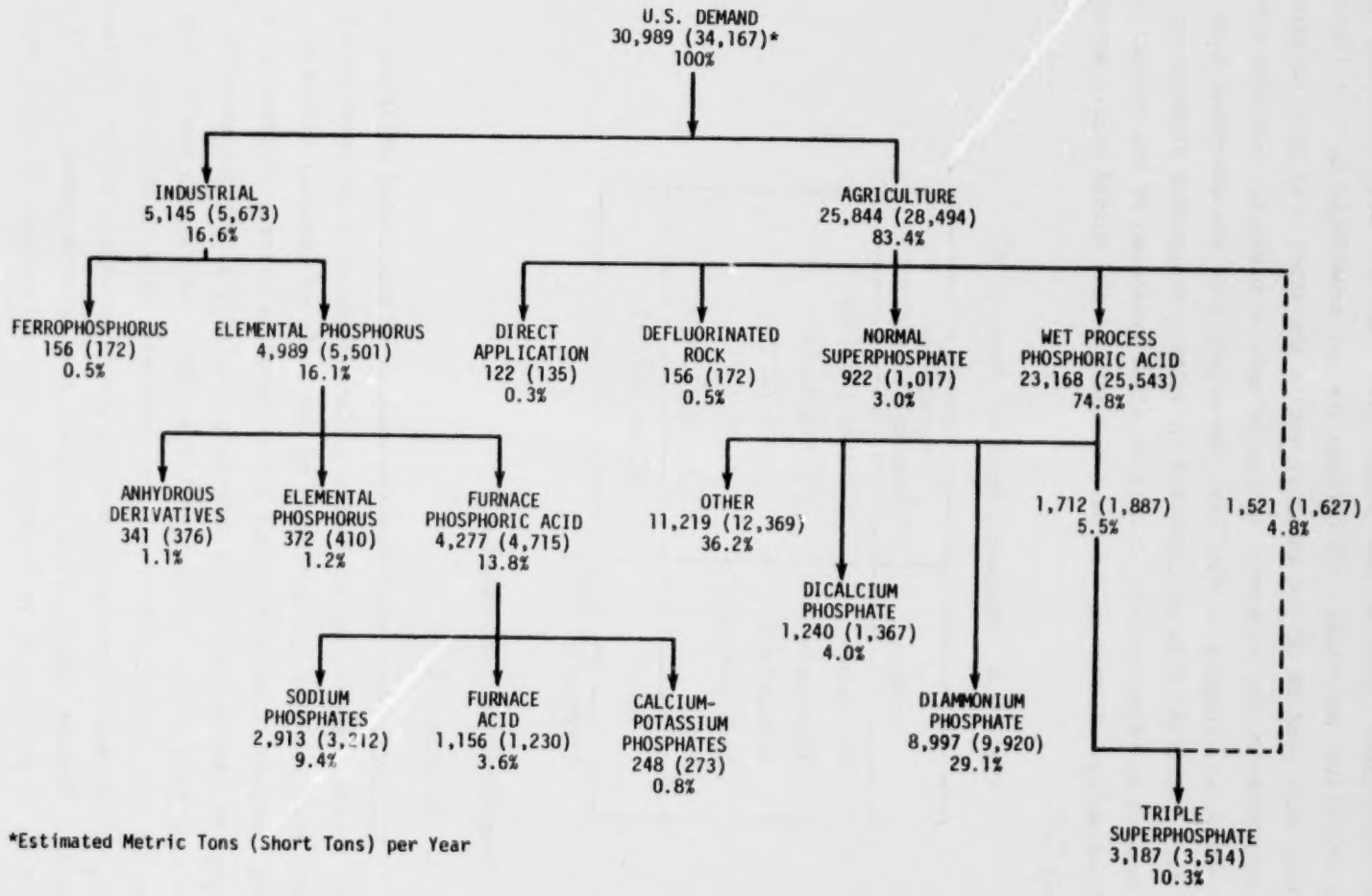


Figure 3.5. U.S. Phosphate Rock Demand Distribution for 1975 (Stowasser 1977a)

66 to 64 percent and 64 to 62 percent. The product's iron oxide and alumina (I&A) content and moisture content are usually limited by contract but combined do not exceed 5 percent (Cathcart 1971).

In preparing the phosphate rock for delivery, wet rock after beneficiation is loaded from storage by gravity onto conveyor belts or into open-top, bottom-discharge hopper cars for transfer to a primary wet rock storage facility. There, the hopper cars are unloaded through an overhead trestle or car shaker, and the product falls onto a conveyor going to storage piles. The material is dumped in piles according to size, BPL grade, I&A content, and other factors by means of a movable stacker or overhead tripper conveyor. On the storage piles, tractors are used to keep the stackers, conveyors, or trestles clear and to move the material back to the reclaiming facilities. A tunnel extending under the length of the storage piles reclaims the wet rock, a conveyor in the tunnel passes it, and from the tunnel, it is conveyed to wet rock feed bins for storage prior to drying.

Wet rock contains from 7 to 20 percent moisture. Since customer contracts normally call for phosphate rock not to exceed 3 percent moisture, all grades of rock are dried to satisfy the required contracted moisture levels. Drying the rock reduces the freight and facilitates the grinding and further treatment at the customers' plants. The two types of dryers used in the field are the rotary and the fluid bed dryers. The rotary dryers, inclined parallel flow units equipped with steel lifting flights, are 2.1 or 2.4 meters (7 or 8 feet) in diameter. The fluid bed dryers operate by hot gases passing up through a perforated grating which propels and dries the rock. The dryers are primarily fired by oil but use natural gas on standby service. The material is discharged from the dryers at a temperature range of 100°C (212°F) to 140°C (284°F) onto conveyor belts going to the dry storage bins.

Some phosphate rock is pulverized at the mines and shipped to the customer ready for acidulation. To accomplish this, the rock is conveyed to the grinder after it has been dried. There, it is ground, the fineness depending on the requirements of the customer, and then conveyed to the storage bin or loaded directly into the car. The grinder discharge is constantly sampled and screen-tested to maintain accurate control on the fineness required. Some phosphate rock is also pulverized for direct soil application,

the fineness being 85 percent less than 0.07 millimeter (0.003 inch) particle size, or finer. This rock is bulk-loaded into cars or is conveyed to a machine where it is normally bagged in 45-kilogram (100-pound) bags.

b. Calcined Phosphate

Some phosphate rock is calcined, i.e., subjected to high temperatures, in order to destroy the inherent organic materials and improve the BPL grade and other characteristics. The phosphate rock is subjected to temperatures of 650-975°C (1200-1800°F) in rotary calcine units that are similar to the rotary dryer in design but are lined with high-temperature ceramics. Because of the calcined rock's high discharge temperature, rotary coolers are used to drop the rock temperature so that the rock can be handled on conveyor belts going to the dry storage bins. For removal of tramp iron materials, the rock is passed from both dryer and calcining unit through magnetic devices.

Three variations of thermal treatment that do not involve reduction are: (1) heating phosphate rock with an alkali salt (e.g., Na_2CO_3) with or without substantial defluorination; (2) heating phosphate rock in the presence of water vapor to defluorinate it as completely as possible; and (3) fusing phosphate rock mixed with magnesium silicate (serpentine or olivine). Following grinding, these products do not require further treatment.

c. Sulfuric Acid

Although sulfuric acid is produced commercially by two basic processes, chamber and contact, the Florida phosphate industry employs the latter process exclusively.

A number of different types of contact plants, normally referred to by the name of the builder or designer of the plant, operate throughout the world; also, contact plants may be further classified according to the raw material source of sulfur used. However, all contact processes consist primarily of the following basic units: sulfur burner, drying tower, converter, absorbing tower, gas cooling equipment such as waste heat boilers and heat exchangers, and required auxiliary equipment.

All producers of sulfuric acid in Florida use elemental sulfur of extremely high purity as the raw material. In the contact process, the molten sulfur is introduced into a sulfur burner along with combustion air which has been predried by being passed through a drying tower containing 93.2-99 percent sulfuric acid. The gases exiting the burner, normally 8-11 percent sulfur dioxide by volume, are cooled in a waste-heat boiler. The cooled sulfur dioxide gas, together with predried air, then enters the solid catalyst converter where it is converted to sulfur trioxide; several different catalysts are available, but vanadium oxide is the most common one in use. The gas exiting the converter is cooled by being passed through a heat exchanger. The cooled gas stream enters an absorption tower where the sulfur trioxide is absorbed countercurrently in a circulating stream of high-concentration sulfuric acid. Normally, absorption efficiency is essentially 100 percent. The sulfur trioxide combines with the water in the acid to form more sulfuric acid, and the acid is withdrawn and stored for use in manufacturing phosphoric acid and other products.

All sulfuric acid plants in the Florida phosphate industry are further equipped with a mist eliminator on the absorber for removing acid mist and spray from the exit gas stream before its release to the atmosphere.

d. Phosphoric Acid

Phosphoric acid is produced primarily by the wet process and the furnace process. The large percentage of phosphoric acid used in phosphate fertilizers is produced from sulfuric acid and phosphate rock. This phosphoric acid, known as "wet-process" acid, is then used in manufacturing triple superphosphate, ammonium phosphate, and other high-analysis fertilizer products.

In producing wet-process phosphoric acid, the primary chemical reaction is between the calcium phosphate constituent of the phosphate rock and sulfuric acid, forming phosphoric acid and calcium sulfate. The principal difference in the processes used throughout the world is the degree of hydration of the calcium sulfate, which can be varied by changing the temperature and P_2O_5 concentration in the reaction. The most popular process used by the Florida producers is the dihydrate process in which $CaSO_4 \cdot 2H_2O$ is precipitated.

Phosphoric acid production by the wet process requires three main operations: (1) reaction between the phosphate rock and sulfuric acid; (2) separation of the gypsum from the phosphoric acid; and (3) concentration of the phosphoric acid to the desired P_2O_5 level. Production units include large reaction vessels in which finely ground phosphate rock is first treated with weak phosphoric acid and then reacted with approximately 55 percent sulfuric acid. Additional process controls must be provided to insure the formation of desired gypsum crystals for efficient washing and proper acid concentrations. The calcium sulfate is then separated by vacuum filtration and thoroughly washed for optimum recoveries of phosphoric acid. The filtration operation produces various concentrations of phosphoric acid, with the weak portions being recirculated for proper process controls. The end product usually contains 28-32 percent P_2O_5. In the final step, the filtration product is concentrated under vacuum and heat to the desired P_2O_5 level, depending on the specific end use, with the highest concentration normally being 52-54 percent P_2O_5. This concentration is used also for acid shipped for fertilizer usages.

The thermal reduction process, which employs either the electric furnace or the modified blast furnace, produces furnace-grade phosphoric acid, which is used primarily for chemical products other than fertilizers but is also used in appreciable quantities by the fertilizer industry. In the thermal process, phosphate rock, coke, and silica are fed to the furnace, usually in a pelletized or nodulized form; when the temperature in the furnace reaches 1110-1320°C (2300-2700°F), the silica and coke react with the phosphate, liberating phosphorus vapor, dust, and carbon monoxide. The dust is removed by passing the total gas stream through a precipitator; after this, the gases are directed to a condenser where the liquid phosphorus is condensed for collection in a sump and filtration before storage. The liquid phosphorus is then burned with air under controlled conditions to produce phosphorus pentoxide. The phosphorus pentoxide is hydrated with water to produce phosphoric acid. Standard concentrations of phosphoric acid produced by this process are 50, 75, and 85 percent H_3PO_4. Two byproducts of the furnace process are slag and ferrophosphorus; a use of the former is as a road base, while the latter is used in manufacturing steel.

e. Triple Superphosphate

Triple superphosphate is a high-analysis product of the reaction between phosphate rock and phosphoric acid containing 45-48 percent available P_2O_5. Phosphoric acid may be made by either the electro-furnace or wet process, but the latter is used predominantly because of economy. Triple superphosphate plants are primarily large units operated as a part of chemical complexes located near the source of phosphate rock; therefore, a large percentage of the world production is in Florida near the major phosphate mining area. Processes vary, but the two major ones are the so-called "solid" and "slurry or quick-cure" processes, both of which Florida producers employ with individual modifications. Triple superphosphate properties depend on the specific process used and the product's granular or nongranular nature. The chemical and physical characteristics of the material depend on the nature of the phosphate rock, including composition (73-77 percent BPL) and degree of fineness [70-85 percent less than 0.07 millimeter (0.003 inch)] as well as the concentration of the phosphoric acid and the method of manufacturing.

In the production of run-of-pile or nongranular triple superphosphate, phosphate rock and concentrated phosphoric acid (50-54 percent P_2O_5) are brought together in a mixer and discharged directly into a continuously moving den as a very dense slurry that solidifies readily into a porous honeycomb-like mass. It is carried to a rotating cutter where it is chopped into particles and then conveyed to the storage area for pile curing; the reaction continues for several weeks. After being cured, the material is reclaimed with power equipment and shipped as run-of-pile triple superphosphate or is granulated by treatment with water and steam in a rotary drum, dried, screened, and shipped as granular triple superphosphate.

In the "slurry" granulation process, the phosphate rock is reacted with relatively weak phosphoric acid (32-40 percent P_2O_5). The resulting slurry is mixed with a large quantity of dried, recycled fine granules, which are coated with the slurry, thus producing the desired granule size. The coated granules are dried and screened, with the product size material being withdrawn to storage and the remainder being recycled to the process. The product is ready for shipment without further curing.

As the reactions occur in all of the various processes, water vapor and gaseous fluorine compounds are volatilized but are absorbed in scrubbing systems before being released to the atmosphere. Fumes and dust from the different operating units are likewise passed through scrubbing systems to control atmospheric emissions.

Triple superphosphate is shipped by rail and is exported through the Florida ports for water shipment. It is used in the manufacture of high-analysis grade fertilizers and also applied directly to the soil as a single nutrient material.

f. Nitrogen-Phosphate (N-P) Products

N-P grade ammonium phosphates are the reaction products of varying degrees of neutralization of phosphoric acid with anhydrous ammonia. The different products marketed worldwide are the result of various processes and modifications and vary widely in nitrogen and P_2O_5 guarantees. The principal grades produced in Florida are from wet-process phosphoric acid and are 18-46-0 (modified diammonium phosphate) (DAP) and 13-52-0* (primarily monoammonium phosphate) (MAP). Other grades, e.g., 16-48-0 and 11-48-0, have been produced in more limited quantities.

Although manufacturing processes and techniques differ among the various area plants, the first step in ammonium phosphate production is the partial neutralization of the phosphoric acid with anhydrous ammonia in a reaction vessel. Water vapor evolves from the heat of the acid and ammonia reaction. The partially neutralized slurry is then pumped to an ammoniator-granulator. There, it is distributed over a rolling bed of recycled fines from the product screening operations, and sufficient anhydrous ammonia is added to produce the desired product grade. From the granulator, the product discharges into a rotary dryer that reduces the moisture content to the desired level. The dryer discharge is fed to a screening section for separation of product size from undersize and oversize materials. The oversize material is crushed and either rescreened or recycled, together with the undersize fractions, back to the ammoniator-granulator. The on-size product from the screening operation is passed through a rotary cooler and then conveyed to storage.

*Total nitrogen % - available phosphoric acid % - soluble potash %.

Ammonium phosphate products are shipped by rail and are exported through the Florida ports for water shipment. They provide the advantages of 2-nutrient content, high water solubility, high analysis, good physical characteristics, and lower transportation and handling costs per unit of plant nutrient.

g. Complete Fertilizer (N-P-K) Products

Granular N-P-K grades may be produced by the addition of potash in the previously described process for N-P products.

h. Superphosphate

Superphosphate, also known as "single superphosphate" and "normal superphosphate," contains between 16 and 20 percent available P_2O_5. The basic process in its manufacture is the chemical reaction of sulphuric acid and phosphate rock. Finely ground phosphate rock [70-80 percent less than 0.07 millimeter (0.003 inch)] containing 31-34 percent P_2O_5 is mixed with 71 to 74 percent sulphuric acid at 49-60°C (120-140°F). The reaction is rapid, producing a liquid slurry that soon solidifies into a porous mass, the speed of reaction being governed by the characteristics of the rock and its degree of fineness as well as by the strength and temperature of acid and the thoroughness of mixing.

Superphosphate is manufactured in single batches or in a continuous process. In batch production, exact weights of rock and acid are simultaneously discharged into a pan and vigorously mixed for 2-3 minutes. The slurry is discharged into a den where the reaction continues. The solidified slurry is excavated and transferred to storage piles for curing while the reaction continues.

Batch production is rapidly being replaced and improved by continuous mixing processes in which phosphate rock, concentrated sulphuric acid, and water are continuously delivered in measured quantities, mixed, moved, cut, and transported by conveyors to storage piles where the material cures for 4-6 weeks. During this period of storage, the mixture is being cured into a finished product of available P_2O_5, which results from the principal reaction of

the rock and acid. During this process, many side reactions occur simultaneously between minor elements in the rock and sulphuric acid, adding micronutrients essential to plant life. Fluorine volatilized during the reaction is recovered through scrubbing systems, yielding hydrofluosilicic acid as a byproduct.

After being cured, superphosphate is ground and used commercially, both in direct application as well as with other plant nutrients in the production of complete fertilizers. Superphosphate production and use are declining because of demand for higher analysis fertilizers.

i. Superphosphoric Acid

Concentrated phosphoric acid produced by either the wet or furnace process is a solution of orthophosphoric acid (H_3PO_4) in water. Water present in the normal concentrations (52-54 percent P_2O_5) is adequate to dissolve the orthophosphoric acid with good physical properties; if the water present is insufficient for the P_2O_5 to form orthophosphoric acid, then nonortho or polyphosphoric acids are formed. Actually, superphosphoric acid is a mixture of several forms of phosphoric acid, the proportions of each depending on the level of P_2O_5 concentration in the product.

Superphosphoric acid is produced from wet-process acid by the evaporation of water to give the desired P_2O_5 content or percent conversion to nonortho forms. The two main types of evaporators are similar to the forced circulation vacuum type used in many wet-process acid plants and the direct heat submerged combustion units; in both types, the acid feed to the superphosphoric acid evaporator is normally 52-54 percent P_2O_5 concentration. Furnace grade superphosphoric acid is produced by absorbing the phosphorus pentoxide gases in less water than normally is used in making furnace phosphoric acid.

j. Animal Feed Grade Phosphate

Phosphate rock is the basic source material in the production of highly purified forms of phosphorus-containing products used as mineral supplements in livestock and poultry feeds. All phosphate ores contain levels of fluorine toxic to animals, so defluorination is required in the production of

feed phosphates. The Association of American Feed Control Officials has established that a feed phosphate product cannot contain more than one part of fluorine (F) to 100 parts of phosphorus (P) and must meet rigid specifications for the other constituents.

The feed phosphates produced by several different companies in the Florida phosphate industry include calcium phosphates, defluorinated phosphates, ammonium phosphates, and defluorinated phosphoric acid. Concentrated wet-process phosphoric acid from which the fluorine has been removed is used in the manufacture of the calcium phosphates, ammonium phosphates, and defluorinated phosphoric acid. The calcium phosphates are produced from the defluorinated phosphoric acid and high-grade limestone, while the ammonium phosphates are produced from the same quality acid and anhydrous ammonia.

Defluorinated phosphates are produced by adding defluorinating agents such as phosphoric acid and soda compounds in controlled amounts to phosphate rock and calcining the mix at temperatures ranging from about 1150 to 1350°C (2400 to 2750°F). All feed phosphate products require guarantees of minimum percent phosphorus (P), minimum percent calcium (Ca), and maximum percent fluorine (F). Ammonium phosphates require a guarantee of a minimum percent nitrogen (N) instead of calcium, as well as guarantees of minimum phosphorus, maximum fluorine, maximum parts per million of arsenic (As), and maximum parts per million of heavy metals reported as lead.

k. Fluosilicic Acid and Related Products

Fluorine compounds are formed and volatilized by heating phosphate rock to high temperatures and by the reaction between phosphate rock and sulphuric and/or phosphoric acids. Liberated fluorine in the form of hydrofluoric acid reacts with silica, forming gaseous silicon tetrafluoride; that, in turn, combines with water, forming hydrofluosilicic acid. Most of the silicon tetrafluoride formed is swept away from the reaction mixture, along with carbon dioxide and other gases liberated simultaneously.

To prevent any possible harmful effects to the environment, gaseous fluorine compounds are removed before the effluent gases are released into the atmosphere. The gases are collected and directed through a series of scrubbing

systems where they are cooled, thoroughly subjected to controlled large quantities of water, and given adequate time and treatment to be efficiently absorbed in the water. From this weak solution, hydrofluosilicic acid is produced for use in the fluoridation of water and is converted into different fluosilicates, fluorides, and other marketable products for many industries.

1. Elemental Phosphorus

Elemental phosphorus is produced by thermal reduction based on smelting phosphate rock with carbon (coke) and a siliceous flux in electric or blast furnaces. The products are elemental phosphorus, ferrophosphorus, carbon monoxide, and calcium silicate. The latter is tapped from the furnace as molten slag. Small quantities of ferrophosphorus produced from the iron in the phosphate rock are tapped from the furnace and marketed as a byproduct.

Elemental phosphorus is used primarily for making inorganic and organic chemicals for use as leavening agents, water softening and cleaning products, plasticizers and insecticides, and many other purposes. Elemental phosphorus is used also for military smoke screens and incendiary bombs, pesticides, and phosphorus alloys.

2. Active Operators

In the 7-county study area, 13 companies are active in processing phosphate chemicals:

- Agrico Chemical Company
- Borden Chemicals
- CF Chemicals
- Conserv Inc.
- Electro-Phos Corporation
- Farmland Industries
- Gardinier Inc.
- W.R. Grace and Company
- International Minerals and Chemicals (IMC)
- Mobil Oil Corporation
- Swift Agricultural Chemicals Corporation
- Royster Company
- USS Agri-Chemicals

3. Potential Effects on Natural Environment

a. Drying and Grinding

Potential environmental effects of the drying and grinding operations are associated with particle escape into the atmosphere. The particles (dust) can escape if dryer gases are uncontrolled, as well as during the grinding process, especially if the materials are particularly dry. Dust can be a significant problem also at each point of transfer of the materials. The size of the dry, ground phosphate rock particle is less than 0.07 millimeter (0.003 inch).

Air passing through the dry rock grinding mill was exhausted through effective bag-type air cleaners to remove entrained rock particles. The trend in new acid plants however is to use wet grinding processes that eliminate the drying process and further reduce the amount of particles released to the atmosphere. In addition, the hard-surfacing of roads and parking lots at plant sites and points of material transfer, as well as the use of landscaping techniques, tend to reduce fugitive dust (particulates) emissions.

b. Sulfuric Acid Manufacture

Gaseous oxides of sulfur are inherent in producing sulfuric acid from elemental sulfur. The gases, SO_2 and SO_3 (sulfur dioxide and sulfur trioxide), are normally removed from the process emission train by single and double absorption towers and ammonia scrubbers. Mose sulfuric acid plants have single absorption towers, which reduce SO_2/SO_3 emissions from more than 45 kilograms (100 pounds) per ton of sulfuric acid to less than 4.5 kilograms (10 pounds) per ton. Double absorption will reduce emissions to under 1.8 kilograms (4 pounds) per ton. Several plants retaining the single absorption unit add an ammonia scrubber to recover SO_2/SO_3 as ammonia sulfate to meet air emission standards (McNeill 1977b).

The manufacture of sulfuric acid also requires large quantities of water for cooling and as a part of the SO_3 reaction in producing the acid. In addition to the water use impacting water resources, cooling activities impart a thermal load to both the atmosphere and the water receiving bodies. There are also potential environmental problems posed by occasional spills or leaks of acid into cooling waters, which could cause fish kills and damage the aquatic environment of receiving waters.

Water recirculation systems involving cooling towers or pond systems would significantly reduce water usage, tend to eliminate thermal pollution, and enhance the potential to contain any spills or leaks. Alarm systems such as pH recorders installed on the closed water-circulation systems thermal pollution and spills or leaks. Also, containment systems involving dikes, emergency containment depressions, and spillways

c. Phosphoric Acid Manufacture

The manufacture of phosphoric acid poses varied potential environmental problems: one is the emission of fluorine gas from the phosphoric acid reactors. All phosphoric acid reactors in the study area are now kept under negative pressure and vented through 2-stage high-energy scrubbers that reduce fluoride emissions (99 percent fluoride removal) to levels not harmful (McNeill 1977b).

Other environmental problems are posed by the process-water handling systems that involve the slurrying and transport of gypsum (filter cake) and the handling of first-stage scrubber waters and other contaminated plant waters. These materials and process waters are circulated through a pond system referred to as the "gyp" pond or "gyp" stack. Gypsum ponds are contaminated with phosphorus, nitrogen, fluoride, and some radionuclides and pose such potential problems as:

- Occasional discharges to the environment because of excessive rainfall, although the waters are generally 100 percent recirculated
- Possible seepage through the dikes and bottom
- Lack of aesthetics exhibited by the large elevated stacks of solid-waste gypsum
- Atmospheric emissions from the pond surface, particularly gaseous fluorine

Fluorine removal by scrubbers can be greater than 99 percent for the industry in central Florida; the collected flourides being circulated through the "gyp" ponds.

Successful treatment of discharges has been demonstrated by the use of a 2-stage process; the first stage generally passes the discharge through limestone (calcium carbonate), which effectively increases the pH to approximately 4.5 acidity (7.0 is neutral on the pH scale); the second stage utilizes hydrated lime and increases the pH to more than 7 (basic). This process reduces fluoride to less than 10 milligrams per liter, phosphate to approximately 30 milligrams per liter and radium to less than 1 picocuries per liter (McNeill 1977b).

A solution to the "gyp" pond seepage problem, as suggested by the EPA, would be to line the ponds with an impervious material to control both dike and bottom seepage. None of the existing "gyp" ponds in the area are lined. Seepage, however, tends to move latterally and is collected in perimeter ditches and pumped back to the ponds.

The accumulation of gypsum at the phosphoric acid plant sites (the production of 1 ton of 30 percent phosphoric acid yields more than 1.2 tons of solid gypsum waste) remains one of the toughest environmental problems to solve. To date, there is no economical means of disposing of the vast quantities of gypsum produced, although some of the material has been used for highway road base.

d. Triple Superphosphate Manufacture

The primary potential environmental problem in manufacturing triple superphosphate is associated with the fluoride emissions from the piles of material stacked in the curing and storage shed. However, the mixers, conveyors, and storage areas are enclosed and kept under negative pressure and are vented through high-energy scrubbers to control air emissions.

e. Nitrogen-Phosphate (N-P) Product Manufacture

The anhydrous ammonia used in producing nitrogen-phosphorus products is a potential source of ammonia emissions to the atmosphere. Process water recirculated through the "gyp" ponds also becomes contaminated with ammonia from the scrubber water and other contaminated streams of the specific product process. The emission of ammonia from the reaction vessels in partially controlled by venting through high-energy scrubbers, no recovery of ammonia per se is effected. The ammonia collected as a mixture with phosphoric acid remains in the "gyp" pond waters which are recirculated. Ammonia is evolved into the

atmosphere during the double liming and settling processes employed to condition excess process water prior to discharge. If lime were added in the secondary process of water treatment to the extent that the pH were raised to between 10.0 and 11.0, ammonia concentrations could be reduced significantly; however, the pH would have to be readjusted to near 7.0 prior to discharge.

f. Feed-Grade Phosphate Manufacture

All feed-grade phosphate products must be defluorinated and purified before being sold. This involves acid-mixing and calcining at high temperatures. The major environmental problems relate to the potential escape of emissions to the atmosphere. These are generally controlled by using scrubbers and circulating the scrubber wash to the "gyp" ponds.

g. Fluosilicic Acid Manufacture

As previously stated, fluorine compounds are formed and volatilized by heating phosphate rock to high temperatures and by the reaction between phosphate rock and sulphuric and/or phosphoric acids; therefore, potential environmental problems center on the control of the resultant gaseous emissions from the production processes and problems associated with the use of large quantities of water.

h. Elemental Phosphorus Manufacture

Potential environmental problems associated with manufacturing elemental phosphorus are keyed to the release of potentially harmful atmospheric emissions resulting from the high-temperature smelting processes. The solutions are similar to those applied to the calcination processes previously discussed.

D. TRANSPORTATION

Transportation is a major element of the phosphate industry, and transportation costs are often a determinant of plant location. The logistics of phosphate rock and fertilizer transportation have changed considerably in the past 20 years and are forecast to continue to change. Current and forecasted trends are toward larger transportation units, which tends to lower

the costs per unit of plant nutrient moved; for example, the transportation of sulfur has been changed essentially from a dry-bulk movement to a molten-liquid-sulfur movement because of unit-cost factors (Sweeney and Hasslacher 1970). Transportation unit-cost factors also predominate within the phosphate production industry; for example, converting from a slurry pipeline to a conveyor system to move mined materials to the beneficiation plants is expected to lower the unit cost (Timberlake 1977).

Primarily, pipelines, conveyors, railroads, highways, and shipping lanes move the materials. The following discussion tracks the transport of materials from mining to consumption. Also refer to Table 3.5.

Table 3.5. Generalized Industry Transportation Listing

Item	From	To	Principal Method	Form
Matrix	Mine	Washer plant	Pipeline	Slurry
Matrix fraction	Washer plant	Flotation plant	Pipeline	Slurry
Sulfuric acid	Sulfuric acid plant	Processing plants	Tank truck	Liquid
Feed	Flotation plants	Processing plants	Railroad	Bulk
Phosphate rock	Beneficiation plant	Port of shipping	Railroad	Bulk
Fertilizer products	Processing plant	Port of shipping	Railroad	Bulk
	Processing plant	Consumer	Truck	Bagged
	Processing plant	Consumer	Tank truck	Liquid
	Processing plant	Consumer	Railroad tank	Liquid

1. Mine Products

Phosphate material (matrix) excavated by dragline is cast into a prepared well where high-pressure water jets create a matrix slurry, which is then moved through pipeline to the washer plant. Alternative transportation methods could include conveyor belts (as is currently under feasibility testing in the study area) or truck or railroad (as may be used in the future when mines and established chemical processing plants become further separated). Also, intermediate washer plants may be incorporated in the flow path to strip out unwanted materials on a preliminary basis, thus reducing the total amount of materials moved.

2. Washer Plant Products

Materials from the mine arrive via slurry pipeline at the washer plant where the initial stages remove the phosphatic slime fraction from the slurry and isolate oversized materials [i.e., particle sizes of less than 0.1 millimeter (0.004 inch) and materials exceeding approximately 7.5 centimeters (3 inches)]; in many cases, the intermediate fraction (or feed) is then reslurried and transported to additional washing/classifying stages at other locations.

Although pipelines are used for reslurried material, conveyor systems are used for some intermediate transfer of deslimed materials prior to reslurrying. One such intermediate transport system is being operated by Brewster Phosphates at its Lonesome Mine. There, after being initially screened and deslimed, the matrix is transported by an overland conveyor belt system consisting of 4,420 meters (14,500 feet) of 137-centimeter (54-inch) wide steel-cable reinforced belt traveling at a speed of 270 meters (885 feet) per minute, which compares favorably with slurry pumping speeds of up to 330 meters (1080 feet) per minute. Unlike conventional conveyors that are powered only at the end, this system is powered by intermediate drive modules spaced at an average of 365 meters (1200 feet). Energy is transferred from electric motors to the belt by steel-belted radial tires than run on, and grip, the edge of the belt. This belt system uses fewer idlers, less massive terminal structure, and simplified takeups (Timberlake 1977). The belt system requires substantially less electric power than a pipeline slurry system, and lower maintenance cost and significantly lower capital replacement cost over abrasive resistant pipe and associated pumping equipment are forecast (Timberlake 1977).

3. Beneficiation Plant Products

Feed to the beneficiation plants for final sizing and flotation processing normally arrives via slurry pipeline. Products from these beneficiation processes are segregated according to particle size and BPL content for eventual drying and sale as phosphate rock or prepared feed for captive wet-acid plants. Normally, materials dried and ground for sale as phosphate rock are reduced to about 3 percent moisture and bagged or prepared for bulk sale.

Materials bound for consumption in the wet phosphoric acid plants are transported primarily by railroad dump cars, a method used also for transferring materials from the beneficiation plants to Florida's three principal ports, Tampa, Boca Grande, and St. Petersburg. Bagged product goes by truck or railroad.

At the beneficiation plant, wet rock in the storage bins is loaded by gravity onto conveyor belts or into open-top bottom-discharge hopper rail cars and is transported to the wet-rock storage facility. The hopper cars are unloaded through an overhead trestle or car shaker onto a conveyor going to storage piles. A movable stacker or overhead tripper conveyor puts the material on the proper storage piles according to size, BPL grade, iron and aluminum content, and other factors. Tractors are used on the storage piles to keep the stackers, conveyors, or trestles clear and to move the material back to the reclaiming facilities. A tunnel extending under the length of the storage piles reclaims the wet rock from storage; the rock passes onto a conveyor in the tunnel from the above storage and is conveyed from the tunnel to wet-rock feed bins. Belts, elevators, and/or table feeders feed the wet rock to the dryers.

Marketable phosphate rock for export or domestic water shipment is transported primarily by rail to port terminals, but contract trucking moves a small quantity from the plants to port terminals, mostly for domestic barge shipment to the upper Gulf Coast area. A small amount of rock is shipped out of the area by rail to domestic fertilizer plants (Sweeney and Hasslacher 1970).

4. Sulfuric Acid Plant Products

The phosphate industry in the study area accounts for approximately 20 percent of the U.S. production of sulfuric acid. Sulfur shipped by suppliers in Louisiana, Texas, and Mexico (and potentially Canada) may be in one of three forms - as liquid, as slate similar to peanut brittle, and in "prilled" form but nearly all received in central Florida is in liquid form. At the receiving point, the liquid sulfur is converted to sulfuric acid for use in the production of phosphoric acid by the wet process.

5. Chemical Plant Products

Fertilizer material is shipped predominantly by rail from study area chemical plants to port terminals for both export and domestic water shipment, although railroads are used also for transporting fertilizer material directly to bulk blenders and other users. In addition, contract trucking takes some bagged and liquid fertilizer products from the processing plants.

E. RECLAMATION OF MINED LANDS

In recent years, reclamation of phosphate-mined lands in the study area has been elevated in importance to not only the local population but the phosphate mining companies operating in the area. Early mining operations were in areas far removed from population concentrations; now, the recent influx of people because of the developing industry, as well as the area's overall desirability for recreation and retirement, has made the industry aware of the benefits that can be derived from reclaimed land.

What constitutes reclamation is subject to both scientific and emotional debate; relative to strip-mined lands, it is generally used synonomously with restoration. For example, Florida's Department of Natural Resources, Division of Resource Management dealing with mine reclamation, defines the terms together as follows:

> "RECLAMATION AND RESTORATION shall mean the filling, backfilling, restructuring, reshaping or revegetation of disturbed lands to a form in which the lands may be beneficially used."

This definition is generally accepted by the industry as well as by others who may benefit from the subsequent use of the land either economically or socially, but environmentalists generally take a more pragmatic position. For example, the Florida chapter of the Sierra Club defines reclamation as follows (USDI Bureau of Land Management 1974):

> "The Sierra Club considers reclamation to have been accomplished only when the mined land has been reconstituted substantially back to the state it exhibited before the mining took place."

These two definitions are not necessarily mutually exclusive, because restoring reclaimed land to its natural state (e.g., as a natural habitat) may be considered a beneficial use of the land; the definitions become polarized when m ined land that was formerly natural habitat is "restored" as a golf course, a park, or a housing subdivision.

Early phosphate extraction practices in the study area involved hydraulic methods without flotation beneficiation and with little consideration of reclamation; what was left behind after mining was a landform consisting of interspaced lakes and ponds and rolling terrain readily susceptible to "recovery" in the form of vegetation reestablishment and wildlife and fish rehabitation. The ponds were generally large and clear and the "hills" dry in contrast to the generally swampy terrain that had existed previously. As the search for minable phosphates moved away from the river courses where hydraulic mining had been used, draglines were introduced. At first, they were small, and draglining with no reclamation left irregular masses of overburden and bodies of water. As draglines became larger, draglining with no reclamation left windrows of overburden, mostly with water in between; this was topographically incompatible with the surrounding countryside.

With the introduction of the flotation process of beneficiation in 1929 came the separation of sand tailings and colliodal minerals (slimes). The most significant adverse effect associated with reclamation of slime ponds results from the difficulties in dewatering. For each hectare-meter or acre-foot of matrix extracted, approximately 1.5 (to 3) hectare-meters or acre-feet of flotation tailings (slimes and sands) are produced (Hoppe 1976); thus, the total volume of material to be disposed of, including overburden, exceeds the original volume, which results in a final positive topographic change without the application of slime dewatering.

In the mid-1950s, several mining companies made efforts dedicated to reclaim mined land, but these efforts generally were confided to small tracts [slightly more than 81 hectares (200 acres)]. These projects were costly because mining had been done without consideration of reclamation.

The early 1960s brought development of a system for reclamation in which it was decided *before* mining what the land should look like *after* mining. Application of the system often results in considerable change in mining procedures. To facilitate land restoration, large tracts of minable land are divided into smaller blocks and the individual mining cuts designed to facilitate not only movement of the draglines and associated pipelines as mining progresses but restoration.

Currently, the phosphate industry in the study area employs land reclamation methods generally proved to be technically feasible and acceptable to the industry on the basis of cost. Within this framework, procedures are determined on the basis of: quantities of material involved (e.g., overburden, clay-slimes, and sand tailings); reclamation objectives (such end uses as wetlands, lakes, residential development, recreational land, improved pastures, citrus groves, etc.); configuration of the property; and unique environmental, social, and economic requirements that might exist for the subject areas.

The industry has expended much effort in recent years to effect cost-effective, acceptable reclamation practices. For example, members of the Florida Phosphate Council* completed reclamation on almost 12,140 hectares (30,000 acres) between 1965 and 1975 and spent nearly $10,000,000 for land reclamation and reclamation research. In 1975 alone, nearly 6,070 hectares (15,000 acres) of reclamation projects were either underway or being completed (Florida Phosphate Council 1976).

Examples of mine land reclamation projects in the study area using currently accepted methods and practices are presented in Table 3.6. An acceptable reclamation practice for at least one operator is as follows:

- Reclamation Planning

  Reclamation plans are an integral part of, and thus impact, phosphate mining plans. Among the most significant considerations are restrictions on the length of mining cuts, placement of overburden, and predetermination of final below-grade locations.

- Disposal of Sand Tailings

  According to CF Mining Corporation (1976), "Sand tailings from the flotation process are pumped from the plant and deposited into open mine cuts as fill material. Water for recirculation can be returned to the recirculating water system utilizing a barge-mounted pump. Deposition of sand fill continues under controlled conditions until design elevations are obtained. The sand is shaped and contoured using conventional earthmoving equipment. Overburden is then placed and compacted into a layer 15 to 30 centimeters (6 to 12 inches) thick over the sand. Seeding with the desired vegetative cover follows."

*The Florida Phosphate Council is a trade association of the following phosphate mining and processing companies: Agrico Chemical Company; Borden, Inc. Chemical Division/Smith-Douglass; Brewster Phosphates (American Cyanamid/Kerr-McGee); Conserv. Department of Philipp Brothers Division of Englehard Minerals & Chemicals Corp.; Electro-Phos. Corporation; Farmland Industries, Inc.; Freeport Chemical Company; Gardinier, Inc.; W.R. Grace & Company, Agricultural Chemicals; International Minerals & Chemical Corporation; Mississippi Chemical Corporation; Mobil Chemical Company; Occidental Chemical Company; Royster Company; Stauffer Chemical Company; Swift Agricultural Chemicals Corporation; T/A Minerals Corporation; USS Agri-Chemicals.

- **Clay-Slime Disposal**

  CF Mining Corporation (1976) says that "Present economically acceptable technology requires clay settling ponds for disposing of clay wastes generated by the beneficiation process. Reclamation by dewatering of clay waste areas using current technology requires approximately 6 to 10 years for completion." Additional sand tailings are used in the construction of slime-pond containment dams.

Table 3.6. Examples of Past Land Reclamation Activities*

Company	Project
IMC	40.5-hectare (100-acre) tract adjoining IMC's Bartow offices, southwest Bartow. Mined 1965-66. Residential sites.
IMC	U.S. 17 strip of 54.6 hectares (135 acres) south of Bartow. Right-of-way for anticipated 4-lane road. Good for commercial.
IMC	12.5 hectares (31 acres) in west Mulberry; 762-meter (2500-foot) frontage on Florida 60. Sold to out-of-state industrial firm.
IMC	8.1-hectare (20-acre) Noralyn recovery plant site; office and lab on reclaimed land.
IMC	404.7 hectares (1000 acres) north, south and southeast of Mulberry; all acreage fronts on highway. One part is recreational and another is agricultural; remainder of reclaimed area is for residential or commercial uses.
Armour	West Bartow Elementary School dedicated in May 1976 and deeded to city in 1960.
Armour	68.8-hectare (170-acre) Clark property. Was swampland prior to mining. A real estate subdivision after reclamation.
Brewster	299.5-hectare (740-acre) Saddle Creek Park with swimming, fishing, picnicing, and other activities, east of Lakeland. Originally a swamp; land was donated to people of Polk County for recreational area.
Brewster	Orange Park north of Lakeland. Mining, with simultaneous reclamation of 900 hectares (2224 acres) that was completed within 1 month after mining.
Brewster	127.5 hectares (315 acres) east of Lakeland donated to Florida Audubon Society as a wildlife sanctuary. Largest reserve owned by society in state.
Mobil	Peace River Park donated to city of Bartow (east of city limits) as recreational area.
Mobil	445.2-hectare (1100-acre) Christina Park south of Lakeland. Sold to private interests for housing development.
Brewster	469.5-hectare (1160-acre) Pleasant Grove Fish Management area east of Tampa. Under supervision of Florida Game and Fresh Water Fish Commission.
IMC	Bartow Civic Center of 4 hectares (10 acres) donated to city for civic center in 1966.
Brewster	652.8 hectares (1613 acres) of reclaimed land in Sydney 15 miles east of Tampa. Sold portion of reclaimed land for 18-hole golf course.
W.R. Grace	Fashionable Sylvester Shores residential subdivision built on reclaimed land in southeast Lakeland. Mined in 1955 and reclaimed in 1960.
W.R. Grace	148.5 hectares (367 acres) in north Mulberry area fronting SR 37 and Carter Road; 792.5 meters (2600 feet) reclaimed on SR 37. Potential commercial and residential property.
W.R. Grace	62.7 hectares (155 acres) in east Mulberry area with 1341.1 meters (4400 feet) on SR 60. Potential commercial property.

*Wright 1974..

Brewster Phosphates is one of the leaders in developing field scale models of slime disposal alternatives. The company does not claim to have eliminated slime ponds but can restrict the enclosing dams to approximately 1.2 meters (4 feet) above ground level compared with approximately 12 meters (40 feet) for conventional slime storage ponds. Brewster is also attempting to confine clay and sand waste disposal to mined-out cuts (Timberlake 1977). The company discussed the sand-clay mix technique as follows:

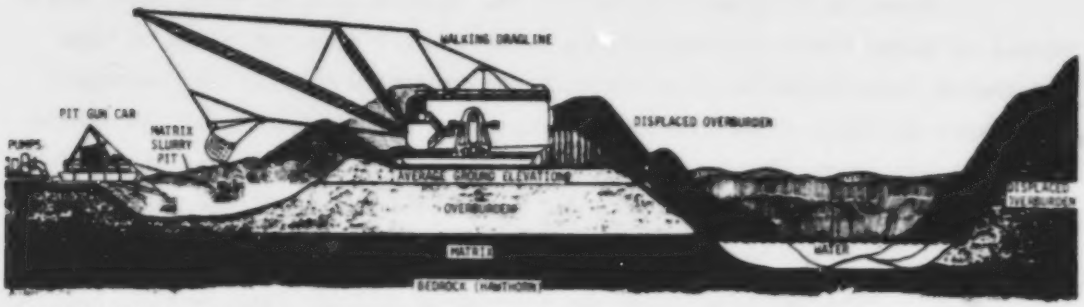
> "The settling areas are surrounded by high dams, and large quantities are stored above natural ground. Reclaiming of settling areas is slow, and the lands restored have very limited use, usually light agriculture or wildlife sanctuaries. In the reclamation technique employed at Brewster Phosphates, most of the waste clays are stored below natural ground where the phosphate clays settle to 12-15 percent quite rapidly. By spraying the tailings sand over the consolidated clays, the sand penetrates and mixes with the clays, liberating water and producing a thick sand-clay mixture. After the mixture has consolidated and the excess water drained off, the overburden is spread over the surface with a wheel excavator and stacker and is graded in a manner which will minimize erosion and facilitate proper site drainage."

Figure 3.6 graphically shows the major steps of the Brewster sand clay method of land reclamation.

According to the College of Engineering at the University of Florida, which has been actively involved in researching the problem of slime disposal (dewatering) for several years, any successful technique must meet the following requirements before it can be implemented on an industrywide basis:

- Low energy requirements
- Applicability at large scale without high capital investment
- Low operation costs
- Technical feasibility

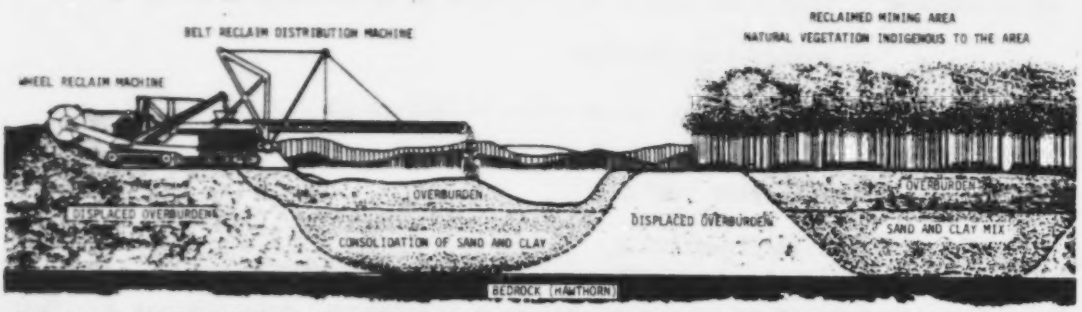
Many techniques found to be successful on a laboratory scale are not applicable on an industry scale; however, progress in the laboratory has led to progress in the field. It was discovered early that the more exotic the dewatering process (e.g., sedimentation of flocculated slimes, freezing, and centrifuging),



MINE CUT

ADDITION OF PHOSPHATIC CLAYS

ADDITION OF SAND TAILINGS



FINAL COVER WITH OVERBURDEN AND DRESS; VEGETATION

Figure 3.6. Brewster Sand-Clay Land Reclamation Method (Timberlake 1977)

the less likely it is that the process will satisfy the criteria. These studies (USDI Bureau of Land Management 1974) found that the most advantageous processes take advantage of natural forces (e.g., gravity) without introducing chemicals (e.g., flocculents).

Construction and operation of slime settling ponds is costly to the industry; reduction in settling areas offers a possibility of substantial savings. Land costs give the industry an added incentive to put mined lands back into productive service. Therefore, the industry has committed itself to reclamation (USDI Bureau of Land Management 1974).

Another incentive to eliminate slime ponds involves the immediate availability of water for recirculation and reuse that would normally be locked up in the slimes for many years. Although vast quantities are recovered by current slime disposal techniques, substantial increases in available water would be forthcoming with the elimination of slime ponds. "The ultimate goal is to mix the clays completely with the sand. Clay particles, due to their small size, can be contained in the voids between the sand particles. This is the way it was before we dug it out of the ground, and someday, we will learn how to put it back that way" (USDI Bureau of Land Management 1974).

For further information on slime pond reclamation please refer to the following paper by Dr. Leslie Bromwell:

"Waste disposal requirements and reclamation techniques of the phosphate industry," In, "Proceedings of the environmental land use planning seminar held in Bartow, Florida, July 27-28, 1977," Texas Instruments Incorporated, 1978.

SECTION 4
PHOSPHATE RESERVES AND RESOURCES

Any estimate of the supply of phosphate rock dictates that a differentiation be made among "reserves," "resources," and "undiscovered resources."

- *Reserves* refer to phosphate deposits that can be mined at or near prevailing market prices.
- *Resources* are deposits that may reasonably be expected to be mined if mining and/or processing technology improves and/or market prices increase.
- *Undiscovered resources* include deposits that may reasonably be expected to be discovered within the time period for the given estimate.

The following paragraphs discuss world, U.S., and study area reserves and resources and depict the role that the industry in the study area plays in supplying U.S. and world phosphate demands. Production and consumption trends, as developed by the U.S. Bureau of Mines and projected to the year 2000, are used herein.

A. GENERAL

The United States is the largest producer and consumer of manufactured fertilizers, and the southeastern states of Florida, North Carolina, and Tennessee are the principal suppliers and exporters of domestically produced phosphate products, including raw phosphate rock. Florida's role in worldwide food production becomes evident when one considers that approximately 80 percent of U.S. output of marketable phosphate rock and approximately 33 percent of the world total come from the Bone Valley formation within the 7-county study area.

Many interrelated factors determine whether a given phosphate deposit can be mined profitably: some are most important; none are totally dominant. These factors include, but are not restricted to the following (Cathcart 1976a):

- The deposit's geologic setting
- The deposit's physical character
- The potential producer's extraction capabilities
- Regulatory policies applicable to the area
- Geographic location
- Projected mining rates (tonnage)
- The deposit's P_2O_5 content or grade

Of the economic factors, tonnage is probably the most straightforward (Cathcart 1976a). Gross tonnages of most marine phosphate deposits (e.g., the Bone Valley deposit) are quite large, but not all of the deposit may be minable because of depth to it, its local thickness, deleterious gangue minerals, and other economic factors. Therefore, tonnages for a deposit must be developed according to the reserve/resource definitions, which are controlled by land, equipment, plant, maintenance, and other inherent costs.

The phosphate content of the rock to be mined is also of prime importance. According to Cathcart (1976b), a phosphate occurrence that contains less than 10 percent P_2O_5 is probably not minable under any condition, whereas a bed containing 30 percent or more P_2O_5 probably is minable if other conditions are favorable. Also, about 12 percent P_2O_5 is the minimum grade for unconsolidated material that can be concentrated by existing processes and about 18 percent for consolidated material that can be upgraded by disaggregation and flotation. About 20 percent P_2O_5 is required if a consolidated deposit is to be used for direct application to the soil, about 24 percent for furnace feed, and about 30 percent for acidulation.

Table 4.1 gives the percentage distribution of the marketed phosphate rock in the United States by geographic areas for 1973 and 1974 in terms of BPL (1.0 percent BPL = 0.458 percent P_2O_5). Reviewing these tabulations reveals why Florida (and North Carolina) are important to the domestic fertilizer market: the generally higher BPL content of the deposits, along with their proximity to shipping lanes, permits lower production costs per phosphate unit. Economics have generally forced a large percentage

of lower-grade rock produced in the western states and all of the rock produced in Tennessee to be consumed in electric furnaces for the production of elemental phosphorus (Stowasser 1974).

Table 4.1. Percentage Distribution of Marketed Phosphate Rock in U.S., 1973 and 1974*

	1973				1974			
(percent BPL)†	U.S.	Fla, NC	West	Tenn	U.S.	Fla, NC	West	Tenn
< 60	8.7	0.3	37.7	66.4	5.6	0.2	35.8	19.7
60-66	11.9	9.7	22.8	19.8	20.8	17.0	22.5	75.6
66-70	40.9	45.9	20.4	12.9	42.0	47.2	23.5	4.7
70-72	12.3	14.1	6.0	--	12.2	14.3	3.5	--
72-74	16.7	18.5	12.6	.9	11.6	11.9	14.3	--
> 74	9.5	11.5	.5	--	7.8	9.4	.4	--

*Stowasser 1974.
†Bone phosphate of lime or tricalcium phosphate.

B. HISTORICAL PHOSPHATE ROCK STATISTICS

1. World and U.S. Phosphate Production and Use

Comparative phosphate rock statistics for the United States and the remainder of the world appear in Tables 4.2 and 4.3. As seen in Table 4.2 comparing phosphate rock production for the U.S. with that of South America, Europe, Africa, Asia, and Oceania during 1972-74, the U.S. accounted for 41.6 percent of world production in 1972, 38.9 percent in 1973, and 37.7 percent in 1974. The 11-year (1965-75) history of phosphate rock statistics in Table 4.3 indicates that the U.S. produced 41.2 percent of the world total in 1975 and 41.7 percent in 1976. U.S. production of phosphate rock over the period of record was somewhat cyclic but steadily increased: the 26,740,000 metric (29,482,000 short) tons produced in 1965 increased to 44,136,000 metric (48,662,000 short) tons in 1976, a 65 percent increase over the period of record; also the demand for phosphate rock in the U.S. increased from 19,832,000 metric (21,866,000 short) tons to 31,291,000 metric (34,500,000 short) tons, an increase of 58 percent.

Table 4.2. World Phosphate Production, 1972-74*

	Thousands of Tons [metric (short)]**					
	1972		1973		1974	
U.S.	37,034	(40,831)	38,218	(42,137)	41,437	(45,686)
South America	444	(490)	453	(499)	552	(608)
Europe	22,548	(24,860)	21,374	(23,566)	22,641	(24,962)
USSR	19,718	(21,740)	21,246	(23,424)	22,535	(24,846)
Others	109	(120)	129	(142)	105	(116)
Africa	23,672	(26,099)	27,663	(30,499)	32,731	(36,087)
Algeria	526	(580)	664	(710)	737	(812)
Egypt	513	(565)	550	(605)	550	(606)
Morocco	14,465	(15,948)	16,561	(18,259)	19,323	(21,304)
Senegal	1,419	(1,564)	1,693	(1,866)	1,878	(2,070)
South Africa	1,252	(1,380)	1,365	(1,505)	1,352	(1,491)
Spanish Sahara	150	(165)	697	(768)	2,385	(2,630)
Togo	1,928	(2,126)	2,272	(2,505)	2,479	(2,733)
Tunisia	3,296	(3,634)	3,472	(3,828)	3,883	(4,281)
Others	124	(137)	165	(182)	145	(160)
Asia	6,227	(6,865)	7,421	(8,182)	9,525	(10,502)
China	2,600	(2,866)	3,000	(3,307)	2,300	(3,307)
Christmas Island	1,151	(1,269)	1,537	(1,695)	1,764	(1,945)
Israel	873	(962)	633	(698)	951	(1,048)
Jordan	694	(765)	1,106	(1,219)	1,595	(1,758)
North Vietnam	280	(309)	500	(551)	1,200	(1,323)
Syria	113	(124)	150	(165)	500	(551)
Others	517	(570)	496	(547)	517	(570)
Oceania	1,841	(2,030)	3,072	(3,387)	2,854	(3,147)
Nauru	1,337	(1,474)	2,323	(2,561)	2,287	(2,522)
Ocean Island	503	(555)	744	(820)	561	(619)
World totals	89,045	(98,175)	98,201	(108,270)	109,740	(120,992)

* Stowasser 1975.
**Numbers may not match due to independent rounding.

Table 4.3. Phosphate Rock Statistics, 1965-76* (Page 1 of 2)

	Thousands of Metric (Short) Tons											
	1965		1966		1967		1968		1969		1970	
World production												
U.S.	26,740	(29,482)	35,413	(39,044)	36,071	(39,770)	37,415	(41,251)	34,217	(37,725)	35,136	(38,739)
Remainder of world	37,020	(40,816)	40,044	(44,150)	41,853	(46,144)	46,553	(51,326)	47,956	(52,873)	49,791	(54,896)
Total	63,760	(70,298)	75,457	(83,914)	77,924	(85,914)	83,967	(92,577)	82,172	(90,598)	84,927	(93,635)
Components of U.S. supply												
Domestic mines	26,740	(29,482)	35,413	(39,044)	36,071	(39,770)	37,415	(41,251)	34,217	(37,725)	35,136	(38,739)
Imports	134	(148)	162	(178)	126	(139)	105	(116)	127	(140)	123	(136)
Industry stocks, Jan 1	5,554	(6,123)	5,921	(6,529)	9,177	(10,118)	9,017	(9,942)	12,646	(13,943)	12,423	(13,697)
Total	32,428	(35,753)	41,496	(45,751)	45,375	(50,027)	46,537	(51,309)	46,990	(51,808)	47,683	(52,572)
Distribution of U.S. supply												
Industry stocks Dec 31	5,922	(6,529)	9,177	(10,118)	9,017	(9,942)	12,646	(13,943)	12,423	(13,697)	13,211	(14,566)
Exports	6,642	(7,323)	8,388	(9,248)	9,135	(10,072)	10,974	(12,099)	10,282	(11,336)	10,646	(11,738)
Demand	19,833	(21,866)	24,836	(27,382)	25,307	(27,902)	22,980	(25,336)	23,159	(25,534)	24,637	(27,163)
Apparent surplus (+), deficit (-), supply**	+32	(+35)	-904	(-997)	+1,915	(+2,111)	-63	(-69)	+1,126	(+1,241)	-812	(-895)
U.S. demand pattern* **												
Fertilizer	15,648	(17,252)	19,594	(21,604)	19,967	(22,015)	18,131	(19,990)	18,273	(20,147)	19,439	(21,432)
Detergents	1,864	(2,055)	2,335	(2,574)	2,379	(2,623)	2,161	(2,382)	2,177	(2,400)	2,316	(2,553)
Animal feed	893	(984)	1,117	(1,232)	1,138	(1,255)	1,034	(1,140)	1,042	(1,149)	1,108	(1,222)
Food products	159	(175)	199	(219)	202	(233)	184	(203)	185	(204)	197	(217)
Other	1,270	(1,400)	1,590	(1,753)	1,620	(1,786)	1,470	(1,621)	1,482	(1,634)	1,577	(1,739)
Total U.S. primary demand	19,833	(21,866)	24,836	(27,382)	25,307	(27,902)	22,980	(25,336)	23,159	(25,534)	24,637	(27,163)

* Stowasser 1977b.

** Difference between distribution of U.S. supply and total U.S. supply

***Distribution pattern for 1965-74 was revised, estimated, and proportioned from 1975 data.

Table 4.3. (Page 2 of 2)

	Thousands of Metric (Short) Tons											
	1971		1972		1973		1974		1975		1976	
World production												
U.S.	35,270	(38,886)	37,034	(40,831)	38,218	(42,137)	41,437	(45,686)	44,276	(48,816)	44,136	(48,662)
Remainder of world	48,635	(53,622)	52,742	(58,150)	59,792	(65,923)	67,311	(74,212)	63,281	(69,770)	61,223	(67,500)
Total	83,905	(92,508)	89,776	(98,981)	98,010	(108,060)	108,748	(119,898)	107,558	(118,586)	105,666	(116,500)
Components of U.S. supply												
Domestic mines	35,270	(38,886)	37,034	(40,831)	38,218	(42,137)	41,602	(45,868)	44,276	(48,816)	44,136	(48,662)
Imports	76	(84)	50	(55)	59	(65)	165	(182)	33	(36)	36	(40)
Industry stocks, Jan 1	13,211	(14,566)	10,840	(11,951)	9,524	(10,501)	7,661	(8,446)	6,326	(6,975)	8,515	(9,388)
Total	48,557	(53,536)	47,923	(52,837)	47,802	(52,703)	49,263	(54,314)	50,635	(55,827)	52,994	(58,428)
Distribution of U.S. supply												
Industry stocks Dec 31	10,840	(11,951)	9,524	(10,501)	7,661	(8,446)	6,326	(6,975)	8,515	(9,388)	14,059	(15,500)
Exports	11,416	(12,587)	12,947	(14,275)	12,585	(13,875)	12,605	(13,897)	11,131	(12,272)	9,977	(11,000)
Demand	25,204	(27,788)	26,788	(29,535)	28,328	(31,233)	31,491	(34,720)	30,990	(34,167)	31,292	(34,500)
Apparent surplus (+), deficit (-), supply**	+1,098	(+1,210)	-1,337	(-1,474)	-772	(-851)	-1,168	(-1,288)	--	(--)	-1,426	(-1,572)
U.S. demand pattern***												
Fertilizer	19,886	(21,925)	21,136	(23,303)	22,351	(24,643)	24,846	(27,394)	24,448	(26,955)	25,396	(28,000)
Detergents	2,369	(2,612)	2,518	(2,776)	2,663	(2,936)	2,961	(3,264)	2,913	(3,212)	2,721	(3,000)
Animal feed	1,135	(1,251)	1,205	(1,329)	1,274	(1,405)	1,417	(1,562)	1,396	(1,539)	1,451	(1,600)
Food products	201	(222)	215	(237)	227	(205)	252	(278)	248	(273)	272	(300)
Other	1,613	(1,778)	1,714	(1,890)	1,813	(1,999)	2,015	(2,222)	1,985	(2,188)	1,451	(1,600)
Total U.S. primary demand	25,204	(27,788)	26,788	(29,535)	28,328	(31,233)	31,491	(34,720)	30,990	(34,167)	31,292	(34,500)

In total demand, fertilizers were by far the most important. In satisfying U.S. demands, imports of phosphate rock play a minor role; for example, rock imports for 1976 satisfied less than 0.2 percent of that year's demand (Stowasser 1977b).

Exports of phosphate rock from the U.S. in 1976 are shown by month in Table 4.4. Exports that year totaled nearly 10,000,000 metric (11,000,000 short) tons, or 23 percent of U.S. production (Stowasser 1977a).

2. Study Area's Phosphate Production

Phosphate production began in the study area in the 1880s when river pebbles were discovered along the Peace River. Initially, production was low; 2,720 metric (3,000 short) tons in 1888, jumping to more than 275,000 metric (313,600 short) tons in 1892 (Altschuler et al 1962). According to R.W. Hoppe (1976), production in the area increased to more than 680,000 metric (750,000 short) tons per year by 1900, more than 3,350,000 metric (3,700,000 short) tons by 1930, and 11,800,000 metric (13,000,000 short) tons by 1960, reaching nearly 36,000,000 metric (39,000,000 short) tons in Florida in 1975. In 1976, phosphate rock production in the study area totaled more than 34,500,000 metric (38,000,000 short) tons, with an average BPL grade of nearly 69 percent (McNeill 1977a).

Table 4.5 shows the distribution of potential ore production by the 10 major mining companies operating in the 7-county study area, as currently operated, as well as the life expectancy of their mines as currently permitted.

C. FUTURE PRODUCTION ESTIMATES

Future production of phosphate rock worldwide will be dictated by developing demand and prevailing prices. Since the majority of phosphate rock is used in the production of food, world demand is tied primarily to world population. Price structures that develop over the coming years are more difficult to predict because of the complicated aspects of pricing; these include, but are not restricted to, location of reserves and resources, supply/demand relationships, mineral extraction technologies, and relationships between producing nations (e.g., cartel development). Because of these

Table 4.4 U.S. Exports of Phosphate Rock in 1976 [Thousands of Metric (Short) Tons and Dollars]*

Period	Canada			Japan			Rest of World			Total		
	Quantity [Thousand metric (short) tons]		Value** ($ in thousands)	Quantity [Thousand metric (short) tons]		Value** ($ in thousands)	Quantity [Thousand metric (short) tons]		Value** ($ in thousands)	Quantity† [Thousand metric (short) tons]		Value**† ($ in thousands)
Jan	202	(223)	6,062	164	(181)	8,225	524	(578)	25,527	891	(982)	39,814
Feb	234	(258)	4,472	87	(96)	3,780	366	(403)	14,452	687	(757)	22,974
Mar	208	(229)	5,621	156	(172)	6,018	584	(644)	20,479	948	(1,045)	32,118
Apr	299	(330)	7,281	78	(86)	3,640	541	(596)	18,426	918	(1,012)	29,347
May	210	(232)	5,778	124	(137)	4,733	452	(498)	16,391	787	(868)	26,902
Jun	176	(194)	4,996	46	(51)	1,851	501	(552)	17,979	723	(797)	24,827
Jul	203	(224)	4,525	77	(85)	3,043	518	(571)	17,265	798	(880)	24,833
Aug	103	(114)	3,164	116	(128)	3,743	514	(567)	16,190	735	(810)	23,097
Sep	151	(166)	3,605	105	(116)	3,580	533	(588)	18,036	789	(870)	25,221
Oct	174	(192)	3,911	78	(86)	2,556	290	(320)	8,442	542	(598)	14,909
Nov	294	(324)	5,960	163	(180)	5,989	650	(717)	20,288	1,108	(1,221)	32,237
Dec	205	(226)	4,324	179	(197)	6,152	685	(755)	20,654	1,069	(1,178)	31,130
Year to date	2,460	(2,712)	59,969	1,374	(1,515)	53,310	6,158	(6,789)	214,129	9,992	(11,017)	327,409

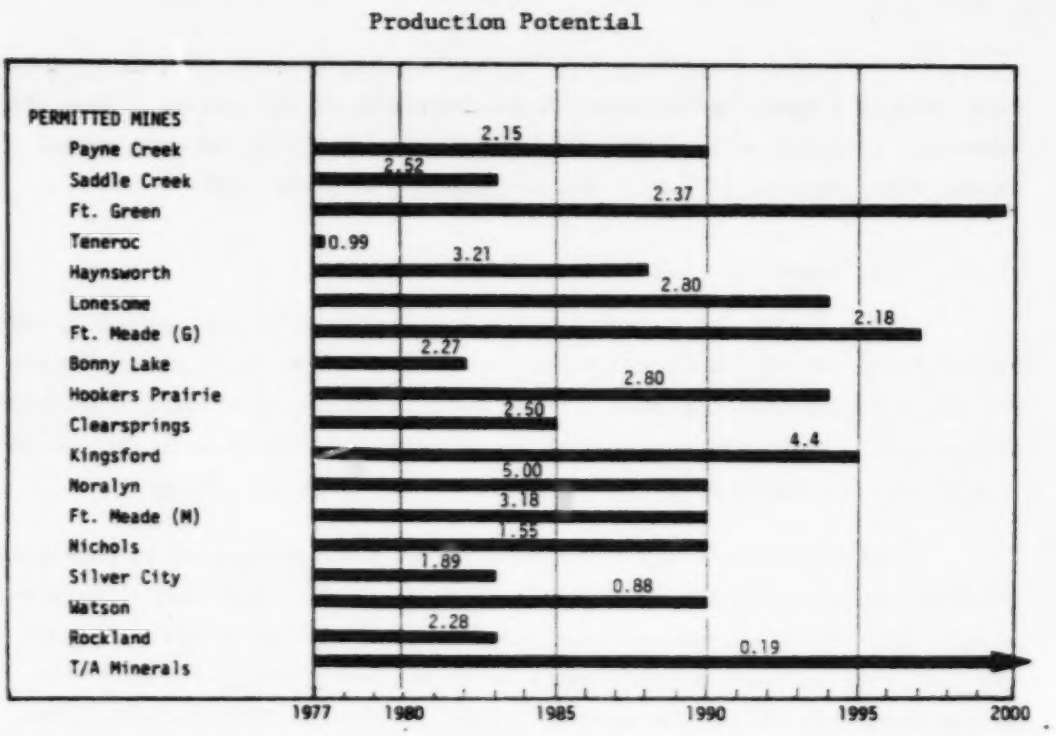
*Stowasser 1977a.

**Declared customs valuation.

†Data may not add to totals shown because of independent rounding.

complications, estimates of future production per se are not aften attempted; instead, demand is estimated assuming that production will track demand. Thus, the terms are considered to be synonymous.

Table 4.5. Major Phosphate Mining Operations in Study Area and Estimated Annual Production in Millions of Short Tons



1. Projection of World Demand

As indicated in Table 4.6, the projection of world demand is an increase from 1975's 99,900,000 metric (110,000,000 short) tons of 147,800,000 metric (163,000,000 short) tons in 1985 and 226,800,000 metric (250,000,000 short) tons by 2000 (Stowasser 1977a).

2. Projection of U.S. Demand

According to Stowasser (1977a),

> "The United States demand is the sum of phosphate rock that is produced in the United States, converted into a product, and consumed in the United States; plus the phosphate rock that is produced in the U.S. and is processed into an intermediate or end product and exported.

> "The majority of this latter classification is fertilizers and is expressed in tons of equivalent phosphate rock. In 1975, U.S. demand was 30,800,000 metric (34,000,000 short) tons, which is projected to increase to 39,000,000 metric (43,000,000 short) tons in 1985 and to 51,700,000 metric (57,000,000 short) tons in 2000."

Table 4.6 summarizes the forecasts (projections) of U.S. phosphate rock demands compared with those of the remainder of the world. These are expressed in terms of high and low forecasts and probable average annual growth rates between 1975 and 1985 and between 1975 and 2000.

3. U.S. Production Estimates

The demand for phosphate rock in the United States, plus U.S. export projections, can be considered equal to the production projections for the U.S. by assuming that internal demands will be satisfied primarily by domestic production. (Future imports may become a very important factor, but at the moment they are ignored because of their historic low percentage.)

The components of the projection for U.S. production of phosphate rock are shown in Figure 4.1. Tennessee production is expected to terminate about 1990. North Carolina production is expected to grow slowly through 1985 and then increase significantly to an estimated maximum mining rate of approximately 18,100,000 metric (20,000,000 short) tons by 2000. Production in western states, including Idaho, Utah, and Wyoming, is expected to increase slowly to approximately 7,300,000 metric (8,000,000 short) tons. Florida production, including that of the study area, is projected to reach approximately 43,500,000 metric (48,000,000 short) tons in 1985 but to decline after 1990 (Stowasser 1977a).

4. Study Area Production Estimates

Figure 4.1 extends the 7-county study area's production estimate to 2020. The curve was developed by assuming that northern Florida's annual production approximates 1,900,000 metric (2,000,000 short) tons, or 5 percent of the state's total and that this percentage will continue (Lockwood 1977). The estimated rate of decline shown for Florida (and hence the study area)

Table 4.6. U.S. and World Phosphate Rock Demand Forecasts, 1975-2000*

	Thousand Metric (Short) Tons										Probable Avg Annual Growth Rate	
	1975		2000 Forecast Range Low		High		1985 Probable		2000 Probable		1975-1985 (percent)	1987-2000 (percent)
U.S.												
Total	30,990	(34,167)	49,885	(55,000)	58,048	(64,000)	39,001	(43,000)	51,699	(57,000)	2.3	2.1
Cumulative	--	--	1,023,096	(1,128,000)	1,081,144	(1,192,000)	351,916	(388,000)	1,033,980	(1,033,980)		
Remainder of world												
Total	68,781	(75,833)	156,004	(172,000)	189,563	(209,000)	108,840	(120,000)	175,051	(193,000)	4.7	3.8
Cumulative	--	--	2,873,376	(3,168,000)	3,116,452	(3,436,000)	1,800,395	(1,985,000)	2,875,190	(3,170,000)		
World												
Total	99,770	(110,000)	205,889	(227,000)	247,611	(273,000)	147,841	(163,000)	226,750	(250,000)	4.0	3.3
Cumulative	--	--	3,896,472	(4,296,000)	4,197,596	(4,628,000)	1,245,311	(1,373,000)	3,909,170	(4,310,000)		

*Stowasser 1977a.

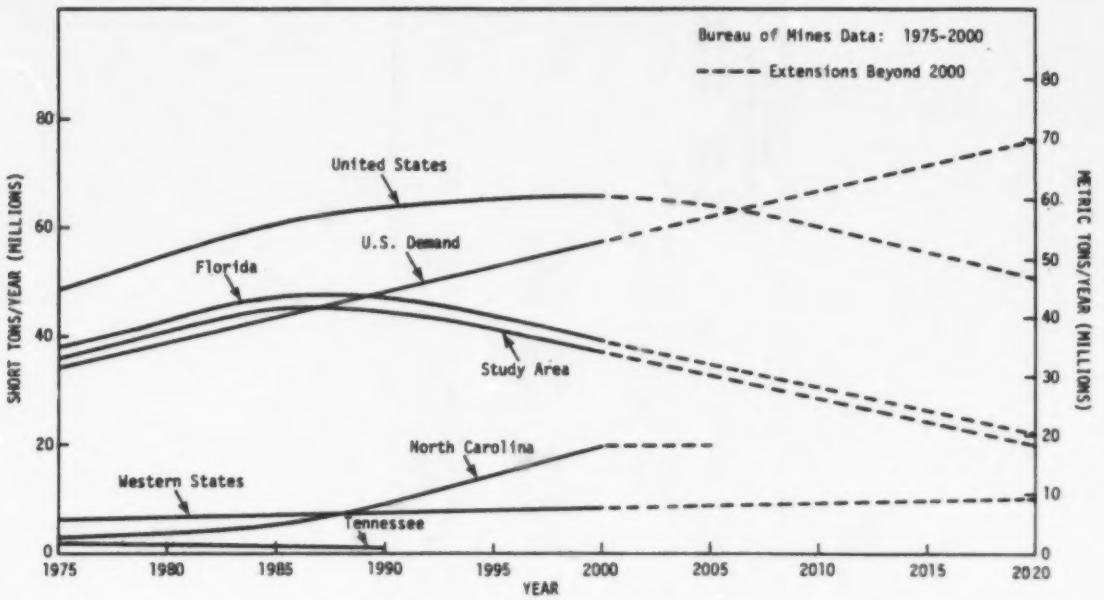


Figure 4.1. Phosphate Rock Supply-Demand Projections (Stowasser 1977a)

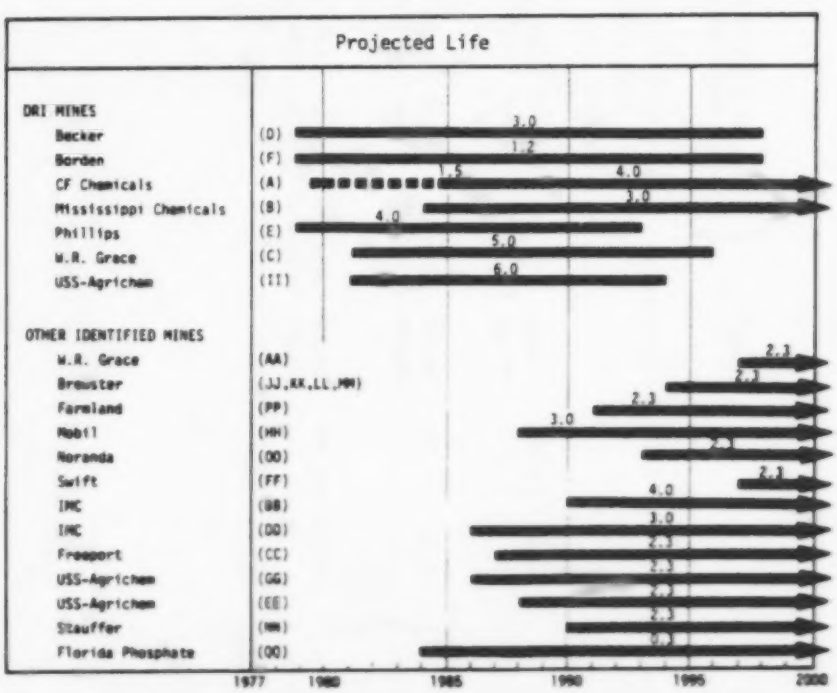


Figure 4.2. Projected Life of Potential New Mines in Study Area (Production estimates in millions of short tons)

assumes that study area properties classified as potential new mines will become active in the late 1980s or early 1990s (Stowasser 1977a). These potential new mines, their anticipated annual production and life span, are indicated in Figure 4.2. Identified are those potential new mines for which applications have been submitted and for which DRIs (Developments of Regional Impacts) exist, and those mines for which applications are likely to be forthcoming from the liated companies.

D. WORLD PHOSPHATE RESERVES AND RESOURCES

1. Definitions and Data

The distinction between various classes of reserves (measured, indicated, and inferred) and classes of resources (hypothetical, speculative, etc.) has been a problem probably since the first attempt at quantifying an ore deposit (Cathcart 1976b). Cathcart uses the term *reserve* to designate phosphate rock for which some physical measurements of thickness and extent have been made and for which there is "reasonable knowledge of tonnage" and to mean that "the material can be mined and processed today at a profit;" he made no distinction between measured, indicated, or inferred reserves. Cathcart defined *resources* as "material for which there is geological information as to extent and thickness, but where drilling is limited or nonexistent, or for deposits that are too low grade, contain too much deleterious elements, or that cannot be mined or processed with existing technology."

Reserves, then, are somewhat limited in terms of years of production that remain. For example, the better grade of reserves in the study area likely will be exhausted before 2000. Additional resources will still be present but will cost more to produce; however, they probably will be mi- able by 2000. Technological improvements could offset some of the anticipated cost increases.

World reserves as well as resources have changed over the past decades as new phosphate fields have been discovered, as metallurgical developments have increased P_2O_5 recoveries from former plant wastes and permitted utilization of lower-grade ores, and as information about existing deposits has increased. Table 4.7, the Bureau of Mines' 1975 assessment of known reserves and resources, shows total U.S. reserves at the time of projection to be 2.27 billion metric (2.5 billion short) tons and the world total to be

total to be 16.1 billion metric (17.7 billion short) tons. The total phosphate rock resources of the U.S. are shown to be on the order of 6.3 billion metric (7.0 billion short) tons, compared with a world phosphate rock resource of approximately 76.1 billion metric (83.9 billion short) tons.

Table 4.7. Assessment of World Phosphate Reserves and Resources*

	Millions of Metric (Short) Tons					
	Reserves†		Other Resources		Total Resources	
North America						
U.S.	2,268	(2,500)	4,082	(4,500)	6,349	(7,000)
Other	<2	(2)	<2	(2)	4	(4)
Total	2,269	(2,502)	4,083	(4,502)	6,352	(7,004)
South America	73	(80)	381	(420)	454	(500)
Europe						
USSR	726	(800)	2,902	(3,200)	3,628	(4,000)
Other	27	(30)	64	(70)	91	(100)
Total	753	(830)	2,966	(3,270)	3,719	(4,100)
Africa						
Algeria	100	(110)	36	(40)	136	(150)
Egypt	181	(200)	181	(200)	363	(400)
Morocco	9,070	(10,000)‡	45,350	(50,000)	54,420	(60,000)
Senegal	118	(130)	64	(70)	181	(200)
South Africa	91	(100)	45	(50)	136	(150)
Spanish Sahara	1,542	(1,700)	1,814	(2,000)	3,356	(3,700)
Tunisia	454	(500)	1,361	(1,500)	1,814	(2,000)
Other	91	(100)	91	(100)	181	(200)
Total	11,646	(12,840)	48,942	(53,960)	60,588	(66,800)
Asia						
China	54	(60)	NA	(NA)	NA	(NA)
Israel	36	(40)	NA	(NA)	NA	(NA)
Jordan	91	(100)	NA	(NA)	NA	(NA)
North Vietnam	64	(70)	NA	(NA)	NA	(NA)
Syria	454	(500)	NA	(NA)	NA	(NA)
Other	18	(20)	NA	(NA)	NA	(NA)
Total	308	(340)	1,814	(2,000)	2,122	(2,340)
Oceania						
Australia	907	(1,000)	1,814	(2,000)	2,721	(3,000)
Pacific Islands	108	(120)	27	(30)	136	(150)
Total	1,016	(1,120)	1,841	(2,030)	2,857	(3,150)
World Total	16,065	17,712	60,027	(66,182)	76,092	(83,894)

NA = not available.

†Estimated recoverable reserves at $27.66 per short ton published by Phosphate Rock Export Association 70 BPL price f.o.b. Florida plant, effective July 1, 1974, and competitively marketed at this selling price.

‡Minimum; reserve may be as large as 40 billion

*Stowasser 1975

2. Variables Influencing Reserve Tonnage

Prices are expected to rise as high-grade low-cost reserves are depleted, turning more and more resources into reserves (Cathcart 1976b). Cathcart points out that "the search for new deposits is continuing and tonnages of reserves will continue to rise, at least for the immediate future. Up to the present time, however, production has come from phosphate rock high in P_2O_5 and low in deleterious elements — aluminum, iron, magnesium, and so on. This premium-grade rock is rapidly being depleted throughout the world, and more and more rock being sold to manufacturers contains larger and larger amounts of the deleterious elements. This is causing problems in processing into fertilizers.

"Most of the tonnage mined today (about three-fourths) is from large low-cost open-pit mines. In the future, more and more rock may come from much higher-cost underground mines than does today. Much of the resource tonnage and a part of the reserve tonnage is from areas that will have to be mined by underground methods. Costs for underground mining are rising all the time; therefore, a part of the reserve tonnage may have to be put into the resource category if costs are too high.

"The geographic location of a deposit may be enough to cause the deposit to be considered as a resource rather than a reserve. For example, there are very large tonnages of phosphate rock in the Sechura desert of Peru. All of this material is considered as a resource because of the location — in a desert on the Pacific Coast of Peru, with no port, no town, no railroad, no fresh water. To mine the material, it will be necessary to build everything, which involves a very high capital investment. The deposit in northern Saudi Arabia is in the same position. Both of these deposits contain large tonnages of rock that can be beneficiated with present-day techniques into a high-grade phosphate product. They are not considered as reserves because of their geographic location. Both of these deposits, however, will certainly be mined in the future.

"• Environmental Considerations

> "Mines and chemical processing plants in the United States are being forced by law to control air and water effluents and to reclaim land after mining. Although this is not

true for most other countries in the world at the present time, there is a growing concern everywhere about the environment, water and air pollution, and land reclamation.

"Certain phosphate deposits that may otherwise be minable may not be mined because of environmental considerations. One example in the United States is the deposit on the Savannah River where the state of Georgia refused to grant permission to mine because the Savannah River and adjacent tidelands would be 'irreparably damaged' by the mining. Thus, at least 1.8 billion metric (2 billion short) tons of recoverable phosphate rock of about 30 percent P_2O_5 must be considered a resource rather than a reserve.

"Demands on the mining industry in the form of very restrictive laws could make open-pit mining virtually impossible, and some legislators have proposed laws that would ban open-pit mining. It is obvious that the mining and chemical industries must make strong efforts to reclaim land as promptly as possible and keep air and water pollution to a minimum in order to avoid serious trouble with county, state, and federal legislatures.

"• Other Variables

"In November 1973, Morocco announced a rise in the price of phosphate rock from $15 to $48 per short ton. Other countries quickly followed, and the net result was a tripling of the price at the mines. The price continued to rise and reached a maximum of $68 per ton early in 1975, when there was the beginning of buyer resistance. At this time, the price dropped and is today at about $22-$27 per short ton.

"The rise and fall of the price of phosphate rock, controlled by one very large producer, influences the amount of material that can be considered as reserve or resource tonnage. At high prices, material can be mined that is marginal or noneconomic during times of low prices" (Cathcart 1976b).

3. World Structure of Phosphate Mining Industry

Cathcart (1976b) further states that "of the total production of phosphate rock in 1974 [99,800,000 metric (110,000,000 short) tons], 75 percent was from three counties — the U.S., 38 percent; USSR, 20 percent; and Morocco, 17 percent. Other North African countries (Algeria, Tunisia, Syria, Jordan, Egypt, and Spanish Sahara) produced about 9 percent of the total. The remaining 16 percent was spread over 30 countries throughout the world.

"The USSR and Morocco have announced plans to substantially increase production capacity, and the United States capacity will also increase if all planned mines are completed. Thus, the percentage of the world production from these countries will increase in the future.

"Morocco, the USA, and the USSR also account for about 75 percent of international export trade. In the decade from 1964 to 1973, a total of about 313,000,000 metric (345,000,000 short) tons was exported — 102,000,000 metric (112,000,000 short) tons (32 percent) by Morocco, 90,000,000 metric (99,000,000 short) tons (29 percent) by the USA, and 46,000,000 metric (51,000,000 short) tons (15 percent) by the USSR" (Cathcart 1976b).

4. Long-Range Forecast

The depletion of phosphate rock reserves, as well as resources that become reserves with time, is keyed to demand. Figure 4.3 forecasts total U.S. and world demand through 2000. The U.S. Bureau of Mines expects domestic demand for phosphate to increase at an annual growth rate of 2.2 percent at least to the end of the century; thereafter, domestic demand may decline to about 2 percent. Earlier in this section, Figure 4.1 showed that the demand curve for the U.S. intercepted the U.S. phosphate rock production curve (as projected) after 2005; thus, the U.S. could still be exporting phosphate rock through this century. Since there are no known substitutes for phosphate rock from which fertilizers can be produced in the quantity needed to sustain world agriculture, programs to increase and conserve domestic reserves and resources most likely will be instituted (e.g., by curtailing exports in the near future).

The world's phosphate reserves and resources except in the United States are owned or controlled by the government of the country in which the deposit occurs. Many countries permit participation by private ownership, but control still rests with the government. Patterns of world trade in phosphate rock are not likely to change drastically until the end of this century. At that time, Australia may become a large producer (and exporter), with much of its production probably going to Japan, cutting sharply into U.S. exports of phosphate rock. This change in the export patterns is expected to coincide with the decline in Florida production (Cathcart 1976b).

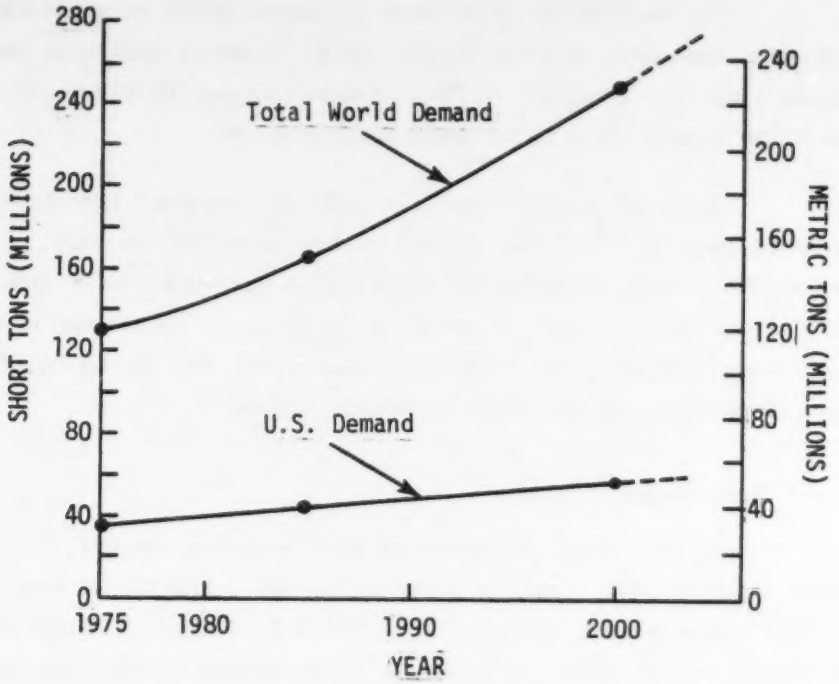


Figure 4.3. World and U.S. Phosphate Rock Demand (Stowasser 1977a)

"The picture for the future, then," says Cathcart (1976b), "would seem to be that Morocco and the USSR will dominate the export buisness and that Australia will take over a part, and perhaps a large part, of the export trade of the United States. It seems likely that the United States will be using almost all production domestically and may become a net importer of phosphate rock in the 21st century."

E. STUDY AREA PHOSPHATE RESERVES AND RESOURCES

In February 1977, the U.S. Bureau of Mines released the results of an analysis of phosphate rock reserves and resources within the 7-county study area. As indicated in Table 4.8 which tabulates results, Polk County reserves are more than twice those of any other county of the study area, but its resources are less than one-third those of Hardee County, the leader for resources among the study area counties (Stowasser 1977a).

Table 4.8. Estimated Phosphate Rock Reserves and Resources in 7-County Study Area*

County	Recoverable Phosphate Rock			
	Measured Reserves [metric (short) tons in millions]		Measured Sub-economic Resources	
Polk	402.7	(444)	95.2	(105)
Hillsborough	181.4	(200)	13.6	(15)
Manatee	164.2	(181)	149.7	(165)
Hardee	176.0	(194)	299.3	(330)
DeSoto	16.3	(18)	63.5	(70)
Sarasota				
Charlotte				
Total	940.6	(1,037)	621.3	(685)

*Stowasser 1977b.

SECTION 5
OTHER RESOURCES OF STUDY AREA

Practically every aspect of our modern way of life depends in some way on mineral and/or energy resources, and our standard of living correlates directly with their development. The affluence of U.S. citizens is contingent on the continued availability of these resources and/or development of reliable substitutes.

Mineral reserves (i.e., unmined resources that can be extracted economically with reference to time) are depletable; generally, when reserves are mined and used, they are lost to society. Thus, mineral shortages can and will occur in the future — and not only because of the physical exhaustion of the minerals but also because of their unavailability at reasonable cost. The cost factor, the major factor in mining mineral reserves, will tend to increase in the future as costs associated with historically externalized economics such as pollution control and land restoration (reclamation) are added to the inflationary costs of mineral exploration, extraction, and processing.

The following subsections discuss the uses and general locations of mineral and energy resources in the 7-county study area. The information has been extracted primarily from the *Minerals Yearbook* (Stowasser and Hendry 1973) and *Environmental Geology and Hydrology of the Tampa Area* (Wright 1974).

A. MINERALS

1. General

Of the total value of Florida's mineral production in 1973, nonmetals represented 70 percent, fuels 28 percent, and metals 2 percent. Except for phosphate rock, most of the mineral production in the 7-county study area is in the form of sand, gravel, crushed limestone, cement, clay, oyster shell, and peat and is related to the construction or service industries. The total value of mineral production in the study area is given by county in Table 5.1. Of the counties for which data exist (DeSoto and Hardee did

not report mineral production in the years stated), Polk and Hillsborough rank among the leaders, primarily because of their direct association with the phosphate industry.

Table 5.1. Value of Mineral Production in Study Area*
(Thousands of Dollars)

County	1972	1973	Minerals Produced in 1973 in Order of Value
Charlotte	**	**	Sand and gravel
Hillsborough	**	**	(Phosphate rock), cement, sand, gravel, peat
Manatee	–	59	Stone
Polk	$155,238	$176,605	Phosphate rock, sand, gravel, stone, peat
Sarasota	**	–	

*Stowasser and Hendry 1973.

**Withheld to avcid disclosure of individual company confidential data.

Table 5.2 compares the values (except where disclosure is withheld) of minerals produced in Florida between 1972 and 1973. Without exception, all minerals increased in value during that period.

2. Sand

a. Construction Sand

Generally, commercially useful construction sand (for example, as used in making concrete) is relatively coarse and is graded to contain grain sizes within specific ranges; sands used in plaster and mortar are usually finer than concrete sand but, like concrete sand, must be clean-graded to specification. Much of the surface of Florida is blanketed with quartz sand, but concrete sand cannot be produced at every site. Wright (1974) reports that the coarsest surface sands in peninsular Florida occur near the center of the peninsula, trend in a nearly north-south direction, and coincide with the general area of the Lake Wales Ridge (Polk County) northward to the Trail Ridge area (see Figure 5.1).

Table 5.2. Mineral Production in Florida as Measured by Mine Shipments, Sales, or Marketable Production (Including Consumption by Producers)*

Mineral	1972 Quantity		1972 Value ($ in thousands)	1973 Quantity		1973 Value ($ in thousands)
Cement						
Masonry [thousand metric (short) tons]	193	(213)	6,901	232	(256)	8,706
Portland [thousand metric (short) tons]	2,200	(2,425)	59,773	2,472	(2,725)	72,666
Clays [thousand metric (short) tons]	836	(922)†	10,336†	1,033	(1,139)	13,718
Lime [thousand metric (short) tons]	163	(180)	3,527	107	(187)	4,026
Natural gas [million cubic liters (feet)]	439,508	(15,521)	4,967	958,729	(33,857)	11,613
Peat [thousand metric (short) tons]	41	(45)	362	40	(44)	384
Petroleum (crude) [thousand 159.0-liter (42-gallon) barrels]		16,897	***		32,695	150,070
Sand and gravel [thousand metric (short) tons]	20,283	(22,363)†	17,009	18,291‡	(20,167)	21,415
Stone** [thousand metric (short) tons]	48,155	(53,093)	81,621	55,994	(61,735)	103,595
Value of items that cannot be disclosed: Clay (kaolin, 1972), kyanite, magnesium compounds, natural gas liquids, phosphate rock, rare-earth metal concentrates, staurolite, stone (shell), titanium concentrates, zircon concentrates, and values indicated by***	NA	(NA)	242,136†	NA	(NA)	214,907
Total	NA	(NA)	426,632†	NA	(NA)	601,100
Total 1967 constant dollars	NA	(NA)	352,014	NA	(NA)	441,328‡

*Wright 1974.

**Excludes shell; included with "value of items that cannot be disclosed"

***Withheld to avoid disclosing individual company confidential data; included with "value of items that cannot be disclosed."

†Excludes kaolin; included with "value of items that cannot be disclosed."

†Revised

‡Preliminary

NA = not applicable

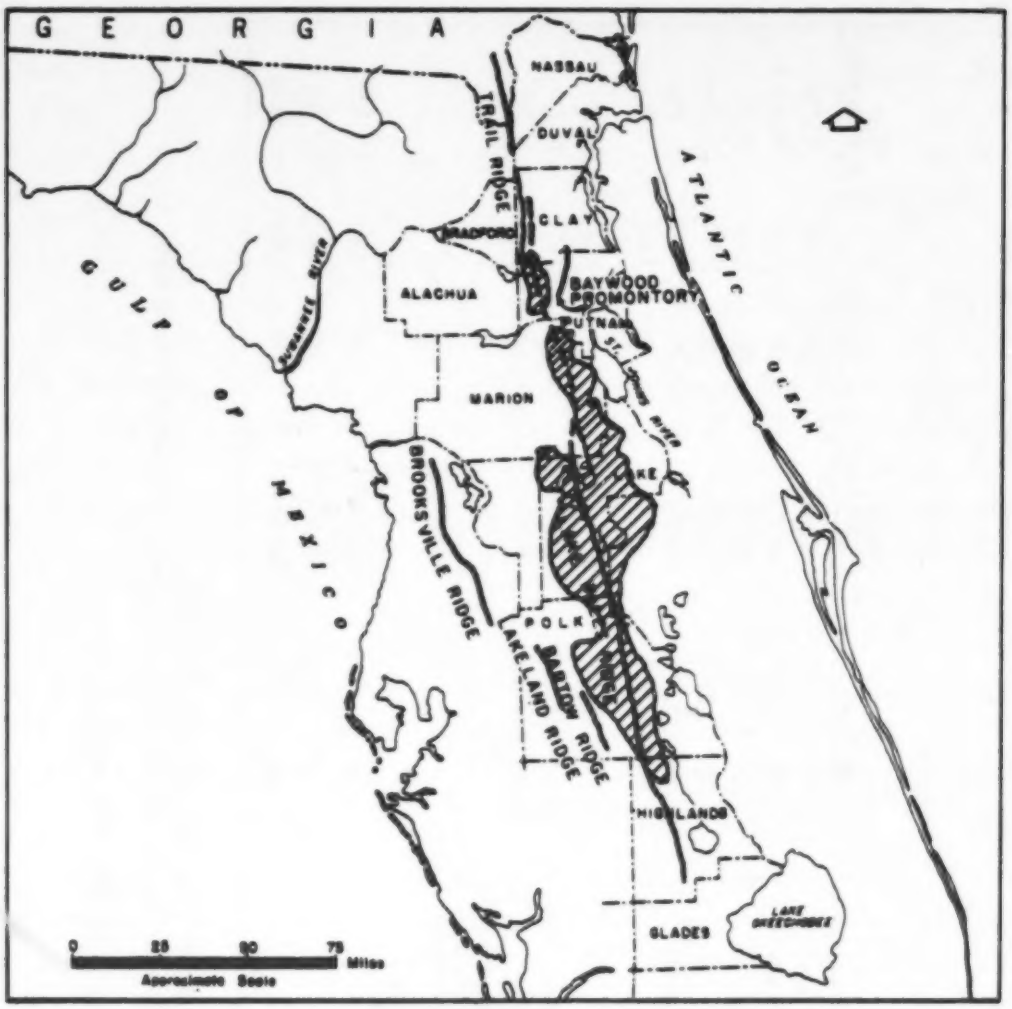


Figure 5.1. Generalized Area of Citronelle Sediments (Cooke 1945)

Coarse sands are extracted from sediments occurring beneath the surface sands. These underlying coarse sands are present predominantly in the Lake Wales Ridge area, but there are minor amounts in the Lakeland Ridge area. These sands of the Lake Wales Ridge are mined from the Citronelle formation, which locally contains concentrations of very coarse sand grains, quarts granules, and small quartzite pebbles; these concentrations of coarse sediments are the materials from which construction sand and gravel are produced. Open-pit mining methods are used. In dry pits, draglines are used; in pits that are partly

water-filled, dredges with barge-mounted pumps are used. Aggregate removed from the pits is washed and sized by screens to meet required specifications of concrete and plaster sands and then shipped by truck or rail to the market area. Data are insufficient for determining the quantity of water used by the sand and gravel industry.

The sand and gravel industry regards transportation as a major cost factor, so various population centers in the study area receive sand and gravel from pits in the Lake Wales Ridge area closest to road or rail; however, some production has come from other localities (e.g., sites located in the Lakeland Ridge area southwest of Bartow in Polk County). Although the number of mines in Polk County remained constant between 1972 and 1973, the quantity sold or used increased. For the entire state, the quantity sold or used was less in 1973 than in 1972, but the value was greater (Wright 1974).

b. Glass Sand

Glass sand must be of very high purity; even a fraction of a percentage of some impurities such as iron will color the glass produced. Glass sand also must have a uniform grade-size distribution of sand particles falling within a range of approximately 0.840-0.149 millimeter (0.003-0.006 inch).

Glass sand is produced in both Polk and Hillsborough counties; in the former, it is mined in the Lake Wales Ridge area near Davenport, where it is separated from the same sediments from which concrete and plaster sands are produced. Special processing, including flotation to remove heavy minerals and other impurities, is required to attain high quality. The glass sand from Hillsborough County currently is produced from surface sand (St. Luci) in the Plant City area. Parts of this deposit are a very high-grade glass sand which, in its natural state, meets high-quality requirements, both texturally and chemically. There are very few natural deposits of glass sand anywhere that meet the quality of these Plant City sands for manufacturing glass. Prior to 1970, flotation was not used in processing the sand; since that date, however, flotation has been used to remove heavy minerals and other impurities to insure a high-quality product.

Similar glass sand deposits have been located in Manatee County, but data are insufficient for determining areal extent and/or thickness. No data on glass sands in other counties of the study area exist.

3. Clay

a. General

Except for reports on commercial deposits of kaolin, fuller's earth, and other specialty type clays, there is little published information on the extent, properties, and potential uses of Florida's clay resources and a paucity of data on clays mined within the study area. However, commercial clays are known to exist in Polk and Charlotte counties.

b. Kaolinitic Clay

The Citronelle sands underlying the north-south-trending Lake Wales Ridge area in the eastern, central, and northern parts of Polk County (previously discussed as the source sediments for quality construction sands of the peninsula) contain varying amounts of kaolinitic clay. This high-quality ceramic clay is disseminated throughout the sands, usually constituting from 2-3 percent to as much as 25 percent of the beds (Wright 1974). In addition to its value as a ceramic clay, kaolinite may be a potential source of aluminum.

c. Fuller's Earth

The Hawthorn formation underlying the phosphate deposits in the area contains fuller's earth, which is utilized for its absorbent properties. The dominant clay minerals are montmorillonite and attapulgite (also see Volume VI, Section 3). Although Hawthorn sediments are present in the subsurface of all seven counties in the study area, no extensive occurrences of this type of clay suitable for mining have been reported; however, the clay is mined extensively in Gadsden County northwest of Tallahassee.

d. Bloating Clay

To explore their potential for economic development as suitable resource material for manufacturing lightweight aggregate, massive bodies of clayey sediments in the vicinity of Charlotte County's Telegraph Swamp have

been drilled and studied within the past few years by members of the Florida Bureau of Geology, the Geology Department of the University of Florida, and the United States Bureau of Mines Laboratories. The clay deposits of Charlotte County have good bloating characteristics across an acceptable temperature range and develop a good cellular structure with a fairly thick and apparently tough wall structure. Currently, however, there is only one lightweight aggregate operation in Florida, and it is near Jacksonville. Wright (1974) reports that extensive deposits of clayey sediments that may have potential as a base material for the manufacture of lightweight aggregate are present also in both Polk and Hillsborough counties.

4. Limestone

Florida's reserves of limestone are monumental. An almost inexhaustible supply exists in the northern half of the state alone, occurring near the surface and having a very high content of calcium carbonate. However, if limestone deposits are to be economically important, they must have natural purity and be easily accessible. Although the study area is underlain by vast quantities of limestone, the thickness of overburden, coupled with the limestone's impure nature, renders the sediment throughout most of the area economically insignificant; however, in a large region about 16 kilometers (10 miles) northwest of Lakeland, the limestone is close to the land surface and is readily mined.

Limestone mined in Florida is used principally as roadbase material, concrete aggregate, and in the manufacture of cement and lime. Other uses include roadstone materials, railroad ballast, and agriculture (fertilizer filler, soil improvement, poultry grit, etc). Also, dolomitic limestones, which are used primarily for fertilizer filler and soil improvement, are mined in Manatee and Sarasota counties.

5. Cement

Cement itself is not a mineral but normally is considered a mineral resource. The raw materials needed in its production are lime or limestone and minor amounts of silica, alumina, and iron oxides. In manufacturing portland cement, raw materials are crushed, then proportioned under strict chemical

controls, ground to a powder or slurry, and fed into an inclined rotary kiln; gravity moves the powdered material from the upper toward the lower end where intense heat is produced, fusing the powdered charge to a glassy clinker composed of calcium silicates and aluminates. The clinker is then mixed with a small amount of gypsum (which later helps to regulate setting time), and the mass is ground to a fine powder referred to as portland cement.

The limestone used in producing portland cement must not contain more than 3 percent magnesia. This stringent requirement eliminates many potential limestone sources. Part of the small amounts of silica, iron oxides, and alumina needed may be present in the limestone as impurities; additional amounts usually are added by introducing clays or other materials containing these substances.

Currently, four plants produce cement in Florida: three are in the Dade County, or Miami, area and one in Hillsborough County in the Tampa area. Although the Tampa plant, with an annual capacity of 6,000,000 barrels of cement, is by far the largest in the state, the Tampa region is experiencing a cement shortage and is importing cement. A new cement plant planned for Manatee County is reported to be pollution-free.

Approximately 87 percent of the cement produced in Florida goes to dealers of building materials and manufacturers of concrete products and ready-mix concrete; the remainder is used by highway contractors and government agencies (Wright 1974).

6. Oyster Shell

For years, Tampa and Hillsborough bays have yielded oyster shell. In 1974, the tonnage was estimated at approximately 400,000 cubic meters (500,000 cubic yards). The amount of reserves is unknown. Most of the oyster shells are used for roadbase materials, and the city of Tampa is one of the largest consumers.

Dredging these shells in the bay area has been the subject of much concern over the past years. Considerations are potential destruction of marine life and biological resources and adverse effects on local water quality.

7. Peat

Peat production is located in Polk and Hillsborough counties; in the latter, it is largely for local needs and comes from sites near Mango. A thorough study of the various kinds of peat and mucks that exist in Florida, including their distribution, origins, and characteristics, was made by Davis in 1946.

8. Vermiculite

Exfoliated vermiculite is produced in Hillsborough County. According to the *1973 Minerals Yearbook*, there was a 72 percent increase over 1972 in the production, quantity sold or used, and sales.

9. Lumber and Related Forest Products

No trees in the study area are harvested except for land clearing during phosphate mining, but the 69,649 hectares (172,101 acres) of forest lands in the study area, representing 4.81 percent of the area, are a potential resource for lumber and related forest products (see Volume IV, Land Use). Wood products, however, are produced in the study area. For example, a saw mill is located in Tampa and a corrugated cardboard box factory is located in Polk County.

10. Heavy Metals

For 60 years, heavy minerals mining has been a small but important industry in Florida. Mined minerals include titanium, garnet, staurolite, tourmaline, epidote, monazite, xenotime, zircon, and aluminum silicates.* Although no heavy minerals production exists in the study area, there are some heavy minerals in the Lake Wales Ridge area.

B. ENERGY RESOURCES

1. General

The study area historically (until the end of 1976) has been 100 percent deficient in internal primary energy resources: all primary energy

*Aluminum silicates are discussed in Volume VI, Section 3, in association with phosphate deposits.

is imported, primarily from other parts of the United States, with some from foreign countries, for direct use or conversion to secondary energy resources (e.g., coal or natural gas to electricity).

Primary energy in the form of liquid petroleum products, natural gas, and coal arrives in the study area primarily through the port of Tampa, with minor quantities via Port Manatee. Railroads and pipelines also serve as import methods. Examples of the quantities brought into Tampa appear in Table 5.3. In 1972, Port Manatee imported 7,900,000 barrels of residual oil, which was barged up the coast to Florida Power Corporation's plant at Crystal River (Wright 1974).

Table 5.3. Primary Energy Sources Received in Tampa Bay Area*

	No. of 159-Liter (42-U.S. gallon) Barrels	
	Year 1971	12 Months Ending 9/30/72
Aviation gasoline	1,168,000	1,597,000
Automotive gasoline	32,994,000	36,849,000
Jet fuel and kerosene	7,253,000	6,103,000
Diesel fuel No. 2	5,944,000	6,820,000
Residual No. 6	14,825,000	12,846,000
Propane	822,000	838,000
Crude oil		556,000
Total liquid	63,006,000	65,609,000
Coal (tons)	2,845,000	3,919,000
Coal (equivalent barrels)**	10,353,000	12,343,000
Total water deliveries***	73,359,000	77,952,000
Gas (million cubic feet)	21,827,000	
Gas (equivalent barrels)†	3,520,000	
Total primary energy***	76,879,000	
Foreign origin‡	11,701,000	11,396,000

Note: Basic data from reports issued by the Tampa Port Authority.
*Wright 1974.
**Assume 3.639 barrels per ton.
***Equivalent barrels.
†Assume 6.32 million cubic feet per barrel.
‡Almost exclusively No. 6 and crude.

Complete dependence on imports could change in the future. For example, the study area could have commercial deposits of petroleum even though DeSoto and Charlotte counties have yielded dry holes (Stowasser and Hendry 1973). In addition, uranium, which could be used for nuclear power plants, occurs in association with the phosphate deposits of the study area and may be commercially developed as an economical energy source (see Section 2). A third potential source is solar energy; although technology for its use is in its infancy, realistic techniques that appear applicable to the area have been demonstrated.

2. Electrical Energy

A network of high-voltage transmission lines criss-crosses Florida, interconnecting the load areas with more than 35 power plants owned by various companies. The value of this interconnection is the high degree of service reliability: power-plant component or transmission-line failures rarely cause serious outages.†

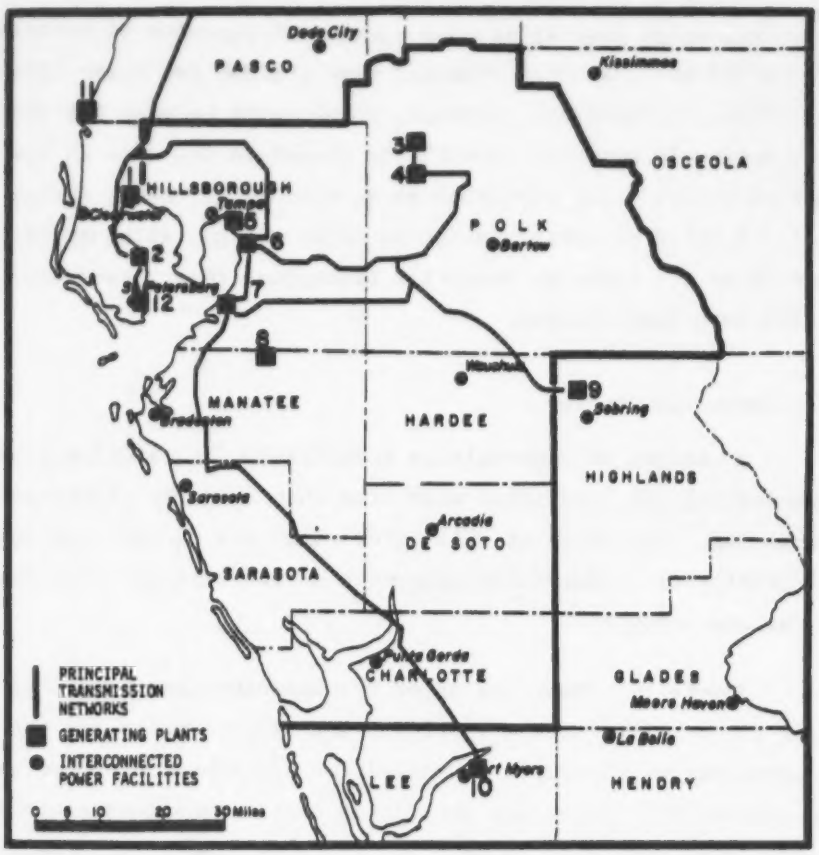
Figure 5.2 shows the major transmission network in the study area, omitting the portions that are rated below 115,000 volts and the many small substations where voltages are reduced for distribution to the various users. At the end of 1972, the power generating stations operating within the study area were those listed in Table 5.4. Examples of user distribution of electrical power in the Tampa area in 1972 appear in Table 5.5.

Table 5.4. Users of Electrical Energy in Tampa Bay Area*

User	Kilowatt-Hours	Percent of Total
Residential	6,007	39
Commercial	3,183	21
Industrial**	4,470	29
Other***	1,598	11
Total	15,258	100

*Wright 1974.
**Approximately 50 percent of industrial use was in phosphate mining and processing industries.
***Includes street lighting and other municipal uses, sales for resale, company's own use, etc.

†An exception occurred in the Miami area on May 16, 1977.



1. FPC's Higgins Plant
2. FPC's Bartow Plant
3. Lakeland Utility's Plant No. 3
4. Lakeland Utility's Larsen Memorial Plant
5. Tampa Electric's Hooker's Plant
6. Tampa Electric's Gannon Plant
7. Tampa Electric's Big Bend Plant
8. FP&L Little Manatee Plant
9. FPC's Avon Park Plant
10. FPC's Ft. Myers Plant
11. FPC's Anclote Plant
12. FPC's Bayboro Plant

Figure 5.2. General Locations of Major Transmission Network with Associated Power Plants (Wright 1974)

Table 5.5. Power Plants in Tampa Bay Area, January 1, 1973*

Company	Capability (megawatts)	Generating Units	Type	Fuel	1972 Net Output (millions of) kilowatt-hours)
Florida Power Corp.					
Bartow	478	3	Steam Turbines	Residual (No. 6) Oil-Natural Gas	3,058
Bayboro	57	3	Steam Turbines	Residual (No. 6) Oil-Natural Gas	229
Higgins	140	3	Steam Turbines	Residual (No. 6) Oil-Natural Gas	780
Bartow	200	4	Gas Turbines	Crude Oil	207
Higgins	164	4	Gas Turbines	Light Oil (distillate)-Natural Gas	115
Tampa Electric Co.					
Hookers Point	201	5	Steam Turbines	Residual (No. 6) Oil	1,079
Gannon	1,082	6	Steam Turbines	Crude Oil	5,136
Big Bend	352	1	Steam Turbines	Crude Oil	1,977
Gannon	18	1	Gas Turbines	Light Oil (distillate)	10
Big Bend	18	1	Gas Turbines	Light Oil (distillate)	
City of Lakeland					
Larsen	127	4	Steam Turbines	Residual (No. 6) Oil-Natural Gas	444
Plant No. 3	103	1	Steam Turbines	Residual (No. 6) Oil-Natural Gas	456
Larsen	39	3	Gas Turbines	Light Oil (distillate)	Included in steam turbines
Plant No. 3	6	2	Diesel	Light Oil (distillate)	
Total Capability	2,975				13,491

*Data supplied by utilities cited in Vernon 1974..

3. Petroleum

Producing oil fields are located in the South Florida Basin east of Fort Myers and in the extreme northwestern portion of the Florida panhandle at Jay (Figure 5.3), but there is no oil or natural gas production in the 7-county study area or any immediate prospects for production. The South Florida Basin fields produce only oil, whereas the fields at Jay produce both oil and natural gas. Most of the crude petroleum produced in Florida is refined into petroleum products at localities outside the state. The study area's petroleum product needs are thus imported.

The pipeline system of Florida Gas Transmission Company, which extends from southern Texas and Louisiana, brings natural gas into the study area where approximately 45 percent is used for generating electricity, another 30 percent is sold directly to large industrial users, and the balance is sold to local distributors for residential, commercial, and small industrial users (Wright 1974). The gas transmission lines in Florida are shown in Figure 5.4.

Figure 5.3. Petroleum Occurrences in Florida (Wright 1974)

4. Coal

Coal originating primarily in the strip mines of western Kentucky and southern Illinois is brought to the study area by barge through the port of Tampa. It is used primarily for the production of electricity.

5. Uranium

Associated with the phosphate deposits of the study area is uranium, which can be economically extracted only during the wet-processing of phosphate (see Section 3). At present, a large quantity of uranium is lost to the products

and process wastes of the phosphate industry; the amount of recoverable uranium lost each year in the products of the industry within the study area has been estimated to be more than 2,000 tons of U_3O_8 (Wright 1974).

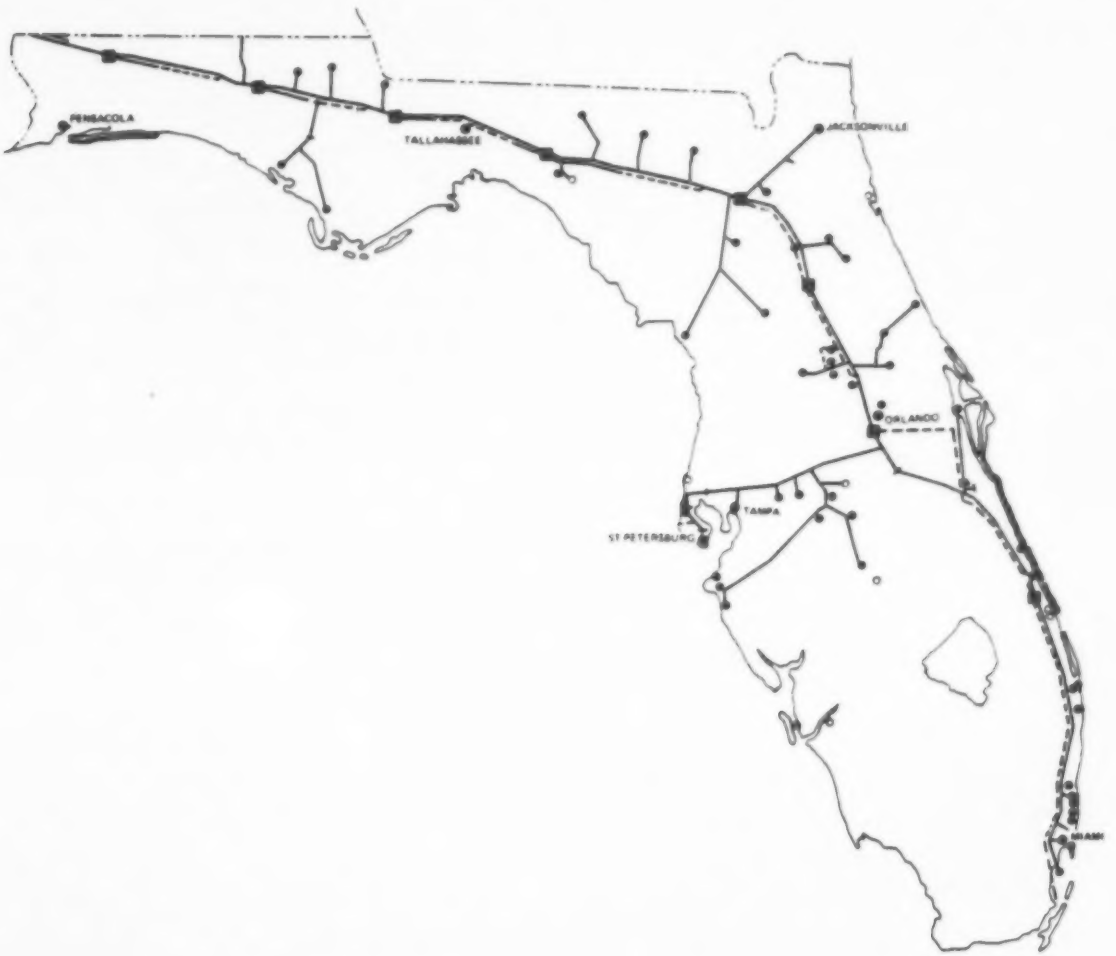


Figure 5.4 Gas Transmission Lines of Florida (Wright 1974)

SECTION 6

INDUSTRIAL TERMINOLOGY (GLOSSARY)

The following glossary contains words in general use as well as terms that are specific not only to the mining and processing industry but to the Central Florida Phosphate District (the latter being indicated by an asterisk (*).

**ALUMINUM PHOSPHATE ZONE*	Zone of supergene leaching and alteration; characterized by white color, high porosity, and aluminum phosphate minerals.
**APATITE*	Taken to mean the mineral carbonate-fluorapatite [$Ca_{10}(PO_4)_6F_2$].
**BEDCLAY*	Plastic water-saturated calcareous clay containing phosphate particles; residum of argillaceous carbonate rock of Hawthorn formation.
**BEDROCK*	Hard calcareous substrate of matrix, usually of Hawthorn formation except at a few localities in the extreme northern part of the district where bedrock is the Tampa limestone.
BENEFICIATION	Combination of chemical and physical processes applied to an ore to remove inert material, thus increasing the concentration of desired minerals.
BPL	Bone phosphate of lime [$Ca_3(PO_4)_2$], tricalcium phosphate equal to percent of P_2O_5 x 2.185.
CALCIUM PHOSPHATE ZONE	Another name for the ore or matrix zone which is that portion of the Bone Valley and the underlying Hawthorn formations enriched in apatite pellets.
CONCENTRATE	Fine phosphate product -1 millimeter to +0.1 millimeter in size and separated from quartz sand by flotation.
DISTURBED LAND	The surface area that is being or has been mined, and all other land areas in which the natural surface has been disturbed as a result of or incidental to the recovery, processing, and marketing of phosphate.

**FEED*	Fraction of matrix smaller in particle size than 1.5 millimeter but larger than 0.1 millimeter. Feed normally undergoes flotation processing but may be marketed as phosphate rock. Sand tailings are derived from this fraction.
FERTILIZER COMPOUNDS	Regular superphosphate (SP), about 18 percent P_2O_5; triple superphosphate (TSP), about 44 percent P_2O_5; diammonium phosphate (DAP), about 18 percent nitrogen, 44 percent P_2O_5; urea-ammonia phosphate, higher N and P_2O_5 than DAP. Complete fertilizer, products of various combinations of nitrogen, phosphoric acid, and potash available to the soil stated in order, e.g., 10-20-10.
FLOTATION	Separation of ore from inert material by reagents that float either the ore or inert materials within an aqueous slurry; reverse flotation involves double action of first flotation of ore, followed by flotation of sand.
LATERITIC WEATHERING	Transformation of ore particles on the surface only.
LEACHED ZONE	Synonymous with aluminum phosphate zone; sometimes used by mining companies for lower, possibly economic part of aluminum phosphate zone.
**MATRIX*	The matrix, the economic zone of the land-pebble commonly referred to as "ore," exists as the unweathered unit of the Bone Valley formation and the underlying residual phosphorite of the Hawthorn formation. Matrix thickness ranges from 0 to 15 meters (0 to 50 feet) and averages about 3.7 meters (12 feet), the thickest commonly being in depressions in the Hawthorn surface (Altschuler et al 1962); in mines currently operational, thickness ranges nominally from 4.5 to 6.1 meters (15 to 20 feet). This unconsolidated mixture of phosphate pellets and granules, cobbles and boulders of phosphatized limestone, quartz sand and silt, and clay ranges in color from green to brown to black. A typical matrix contains about one-third phosphate, one-third silica (quartz) sand, and one-third clay; the bone phosphate of lime (BPL) content, which is calculated as $Ca_3(PO_4)_2$, ranges from 15 to 40 percent (equivalent to 7 to 18 percent P_2O_5). The matrix mined comprises, on the average, about equal parts recoverable phosphate particles ("pebble" and "concentrate"), quartz sand (tailings), and slime (-0.1-millimeter

	material including clay). Depending on matrix thickness and the relative abundance of phosphate particles, the content of recoverable phosphate (P_2O_5) ranges from about 500 tons to about 35,000 tons per acre and averages approximately 5,000 tons per acre (Altschuler et al 1962). Deposits in Polk and Hillsborough counties are of somewhat higher grade than those in Manatee, Hardee, and DeSoto counties (U.S. Bureau of Mines 1975).
MESH	Refers to U.S. Standard (or Tyler) sieve opening. Common mesh/size correlations in millimeters include: No. 14, 1.5; No. 18, 1.0; No. 50, 0.3; No. 150, 0.1; and No. 200, 0.07.
NODULE	This is a rounded, irregular mass of any size. The term may apply to rock fragments as well as apatite particles.
OVERBURDEN	All earth materials, including soil, removed to gain access to the ore (matrix) body in the process of surface mining.
PEBBLE	*Coarse* pebble refers to hard phosphatic nodules usually no larger than approximately 13 millimeters in diameter but larger than 1.5 millimeter; *Fine* refers to hard phosphatic nodules usually no larger than 1.5 millimeter in diameter but larger than 0.8 millimeter.
PELLET	Generally, rounded oviform sedimentary apatite particles that commonly are sand to granule in size.
PHOSPHATE ROCK	Generally, a commercial term for rock containing phosphate materials of sufficient grade and composition to permit its use before or after beneficiation in the manufacture of commercial phosphate products.
PHOSPHORITE	A synonym for phosphate rock in the district; normally used to denote a rock or specimen containing substantial amounts of sedimentary apatite.
RECLAIMED LAND	Formerly disturbed land that has been backfilled, restructured, reshaped, or revegetated, forming land that may be beneficially used; e.g., reclamation may create lakes or ponds that can be used for purposes other than those associated with mining or processing.
SLIME	A clay/water mixture discarded following beneficiation of matrix material; includes clay minerals, fine quartz, and phosphate minerals nominally less than 0.1 millimeter in solid particle size.

SLURRY	A mixture of water and solids that can be pumped and will flow in a pipe or trough.
TAILINGS	Mainly quartz sand less than 1 millimeter but greater than 0.1 millimeter in size, which is separated from phosphate particles by flotation (beneficiation).
TON	Short ton = 2,000 pounds = 907 kilograms; long ton = 2,240 pounds = 1,016 kilograms; metric ton = 2,205 pounds = 1,000 kilograms.

SECTION 7

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